WIMP dark matter and the isotropic radio background connection

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Outline

Introduction

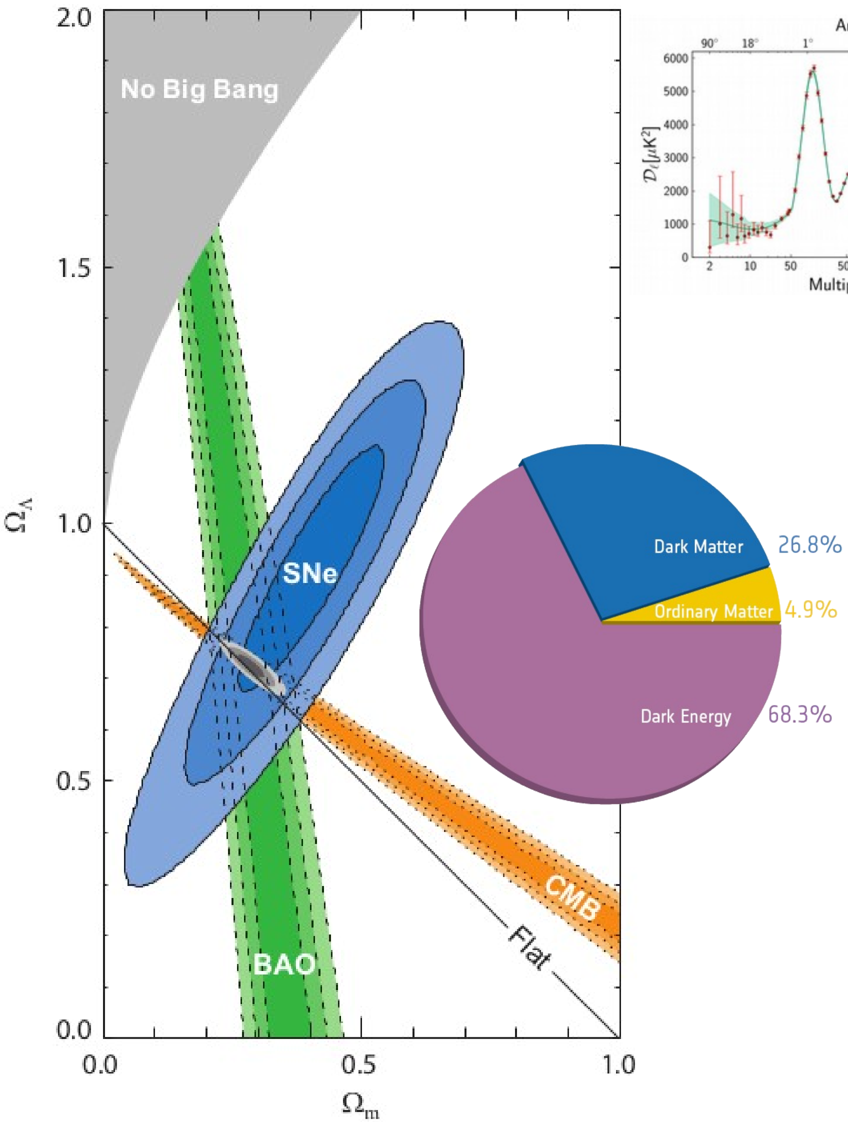
Cosmic ray propagation

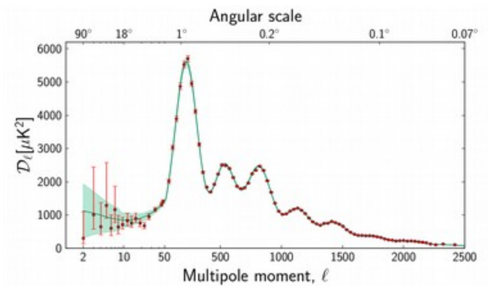
Synchrotron emission

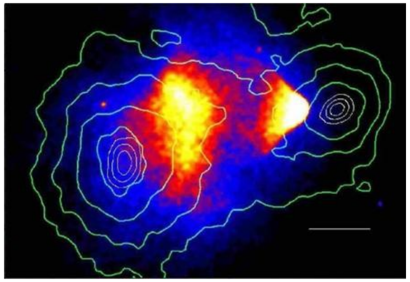
WIMPs @ Radio
- galactic
- extragalactic

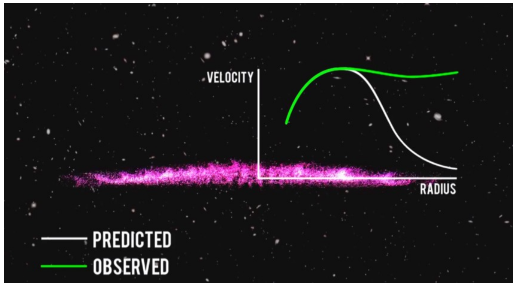
Conclusions

Dark Matter







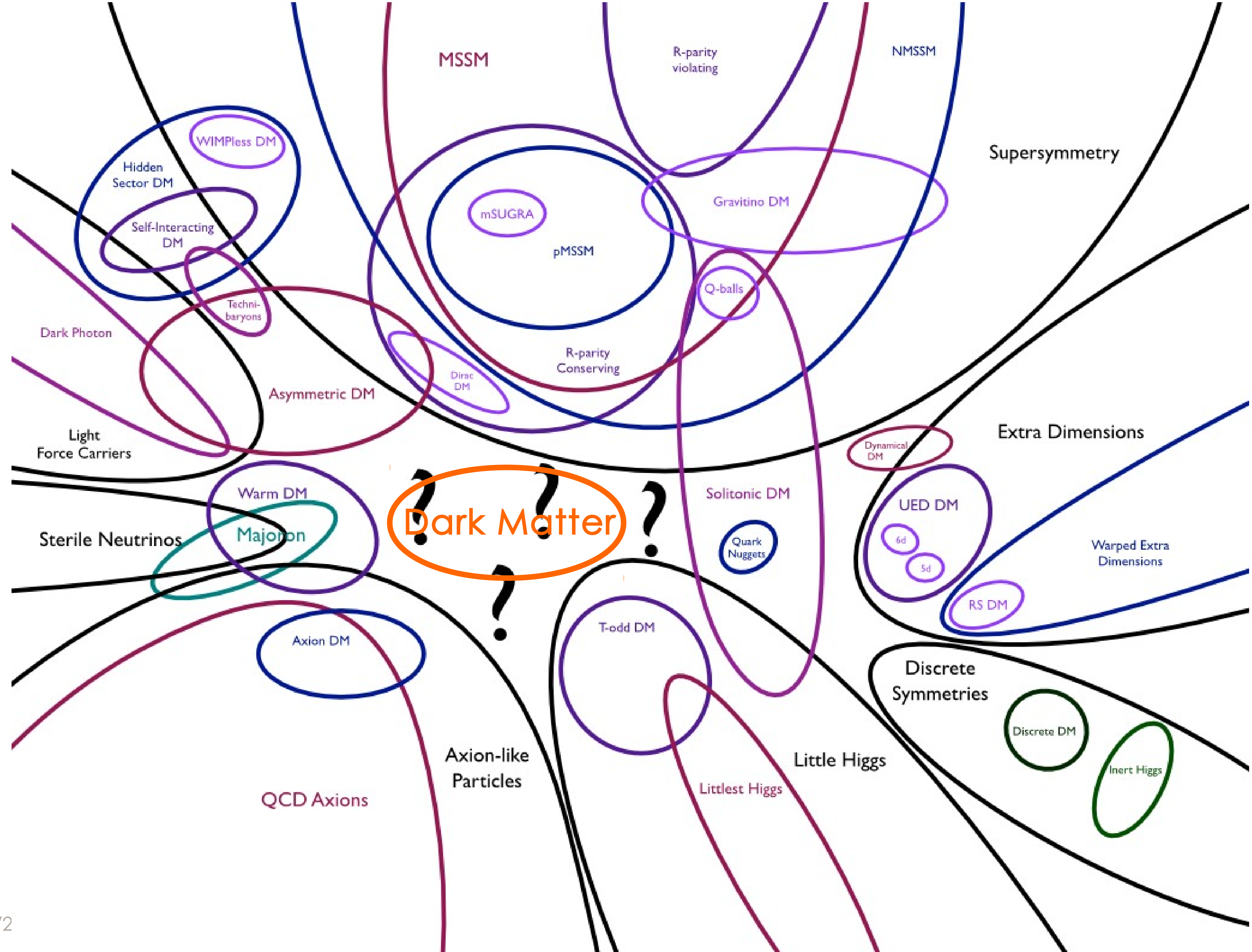


Observations support Dark Matter at:

- Galactic scales
- Galaxy clusters scales
- Cosmological scales

$$\Omega_{\rm DM} h^2 = 0.1196 \pm 0.0031$$

Candidates

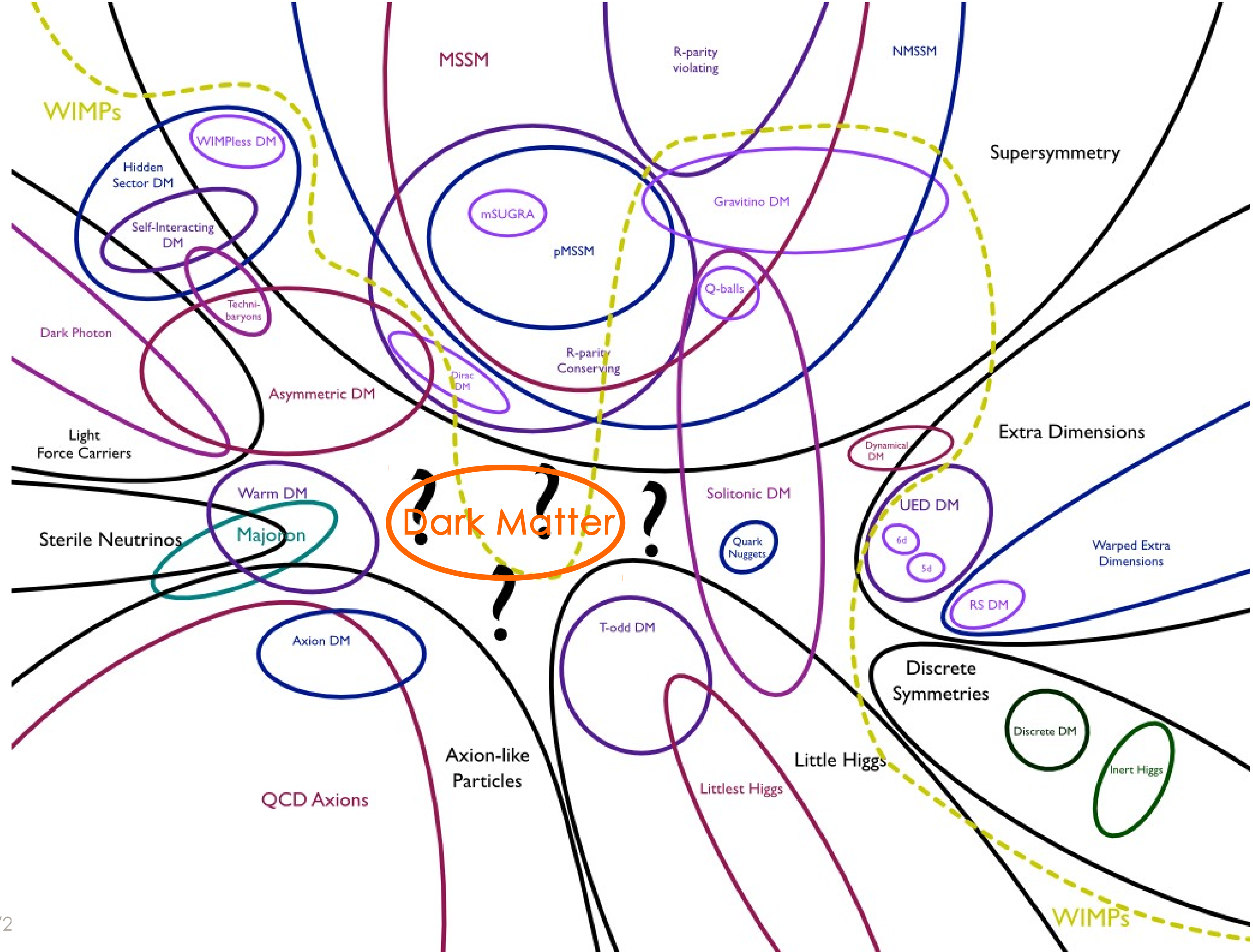


Adapted from arxiv:1401.6085

WIMPs

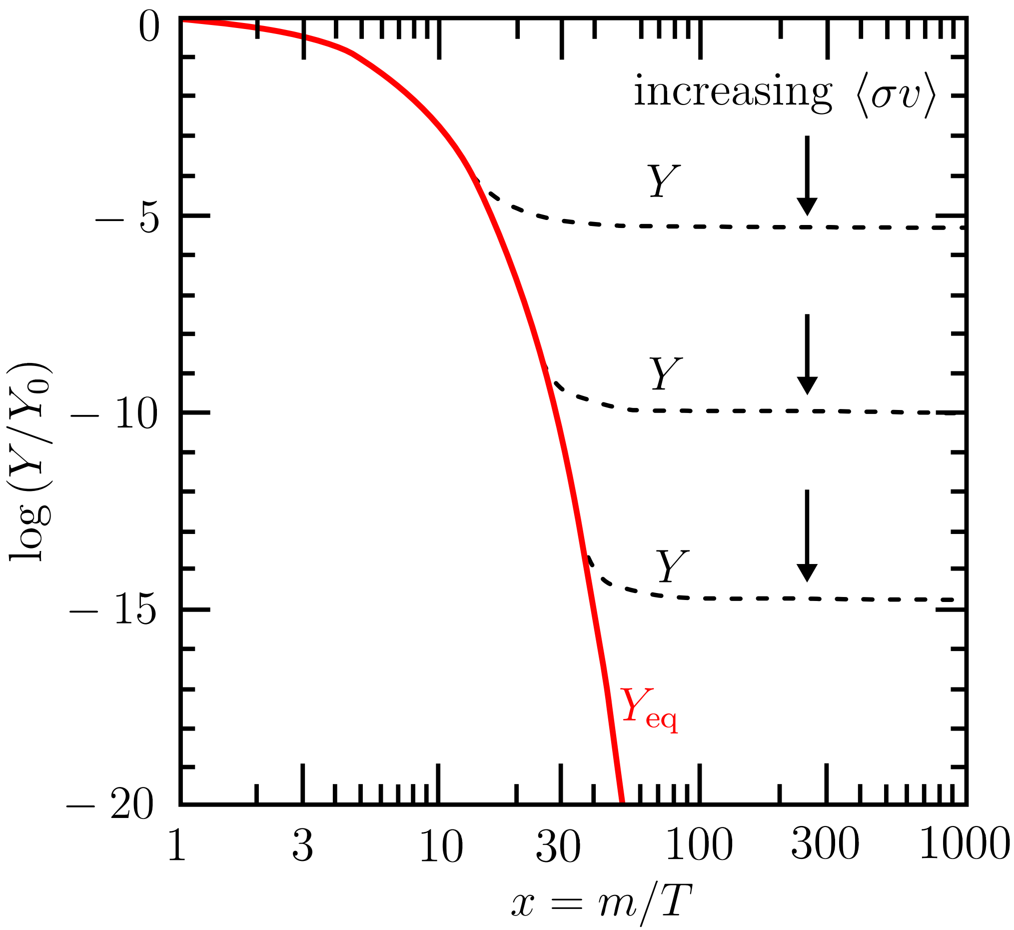
Weakly Interactive Massive Particles

Candidates



Adapted from arxiv:1401.6085

WIMPs



Big Bang Thermal relic

Correct relic abundance

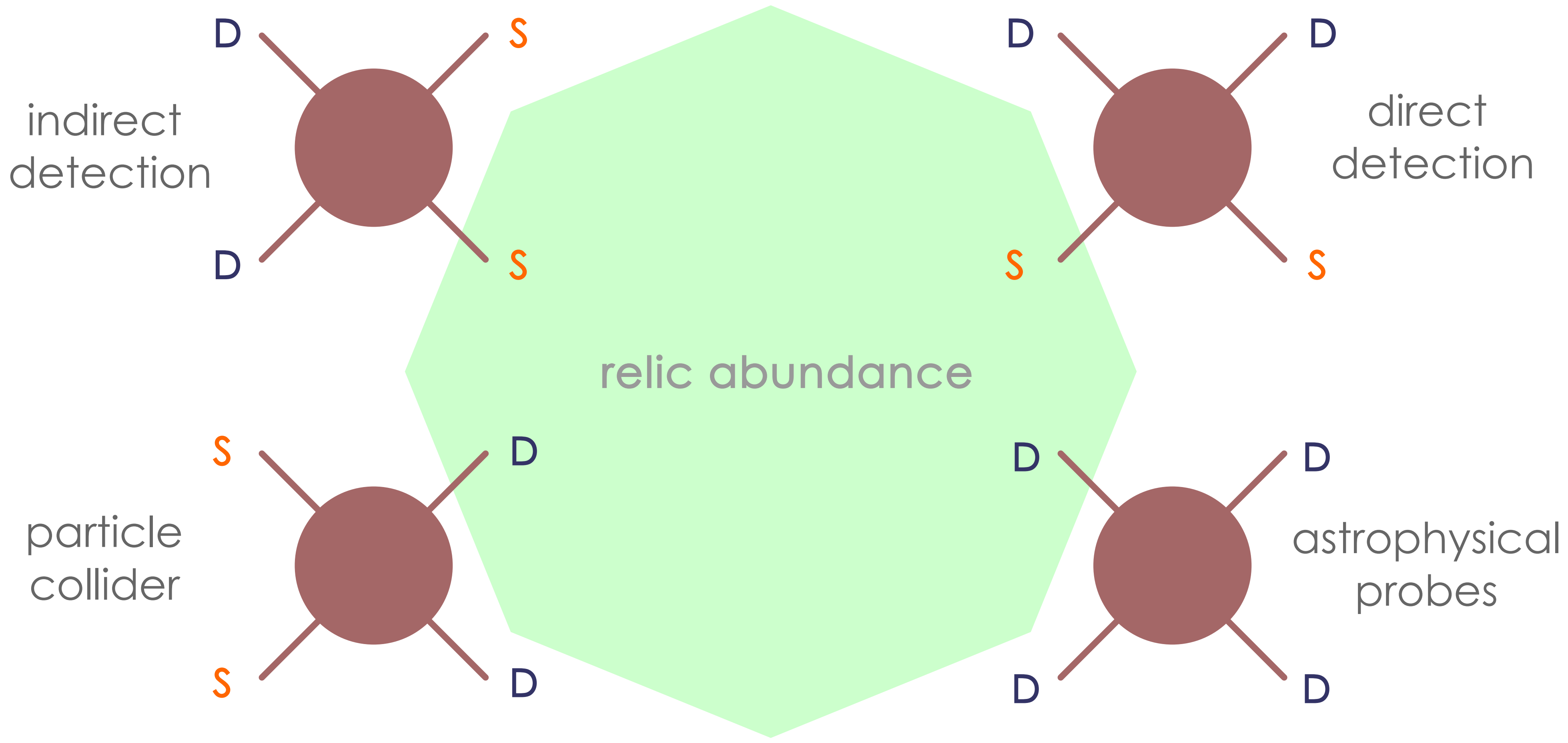
for <σv> ~ 1 pb · c

Mass in GeV-TeV range

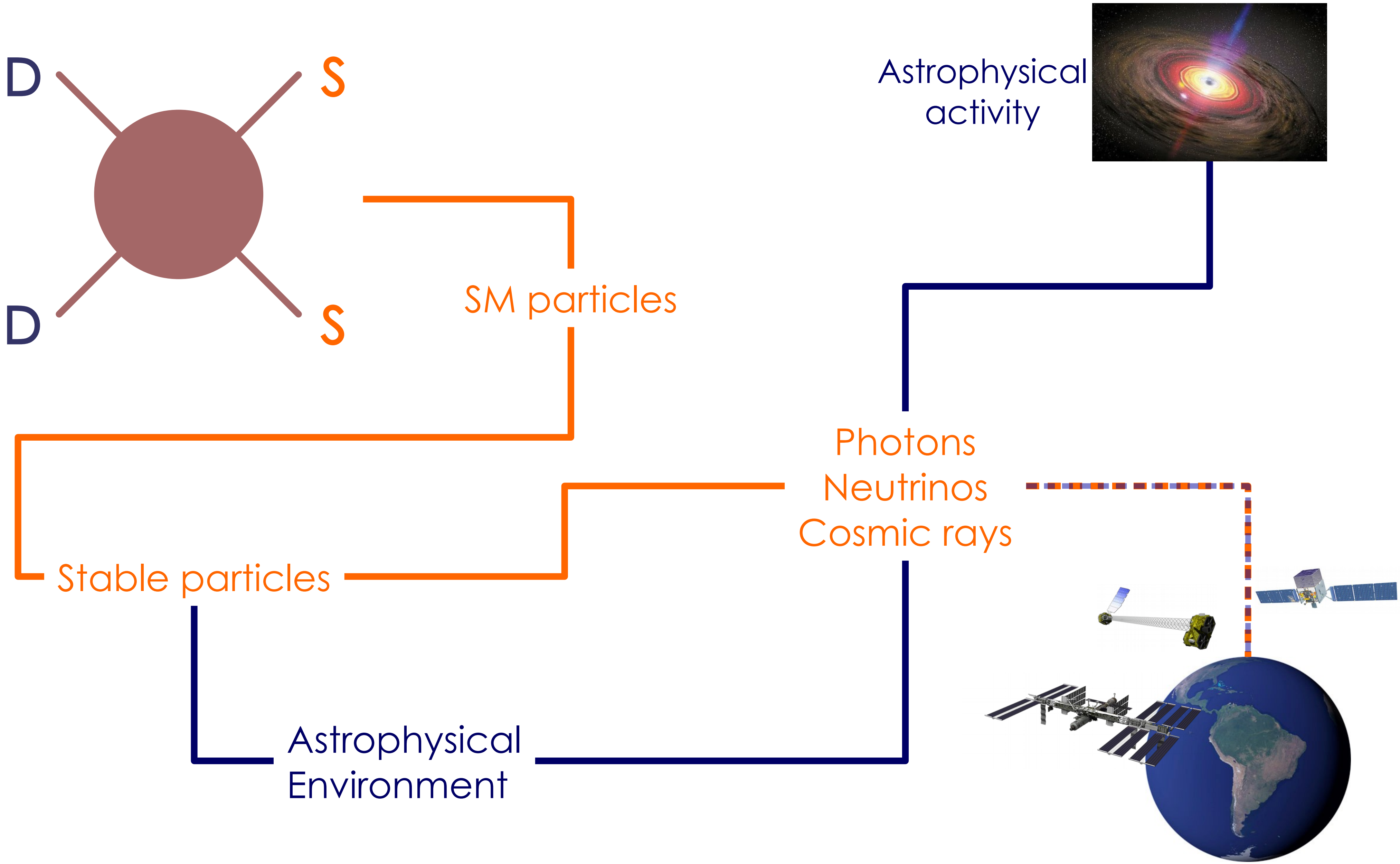
For WIMPs:

$$\Omega_{\rm DM} h^2 \simeq 0.1 \frac{3\times 10^{-26}\,{\rm cm}^3/{\rm s}}{\langle\sigma v\rangle_{\rm f.o.}} \qquad T_{\rm DM}^{\rm f.o.} \simeq \frac{1}{20} m_{\rm DM}$$

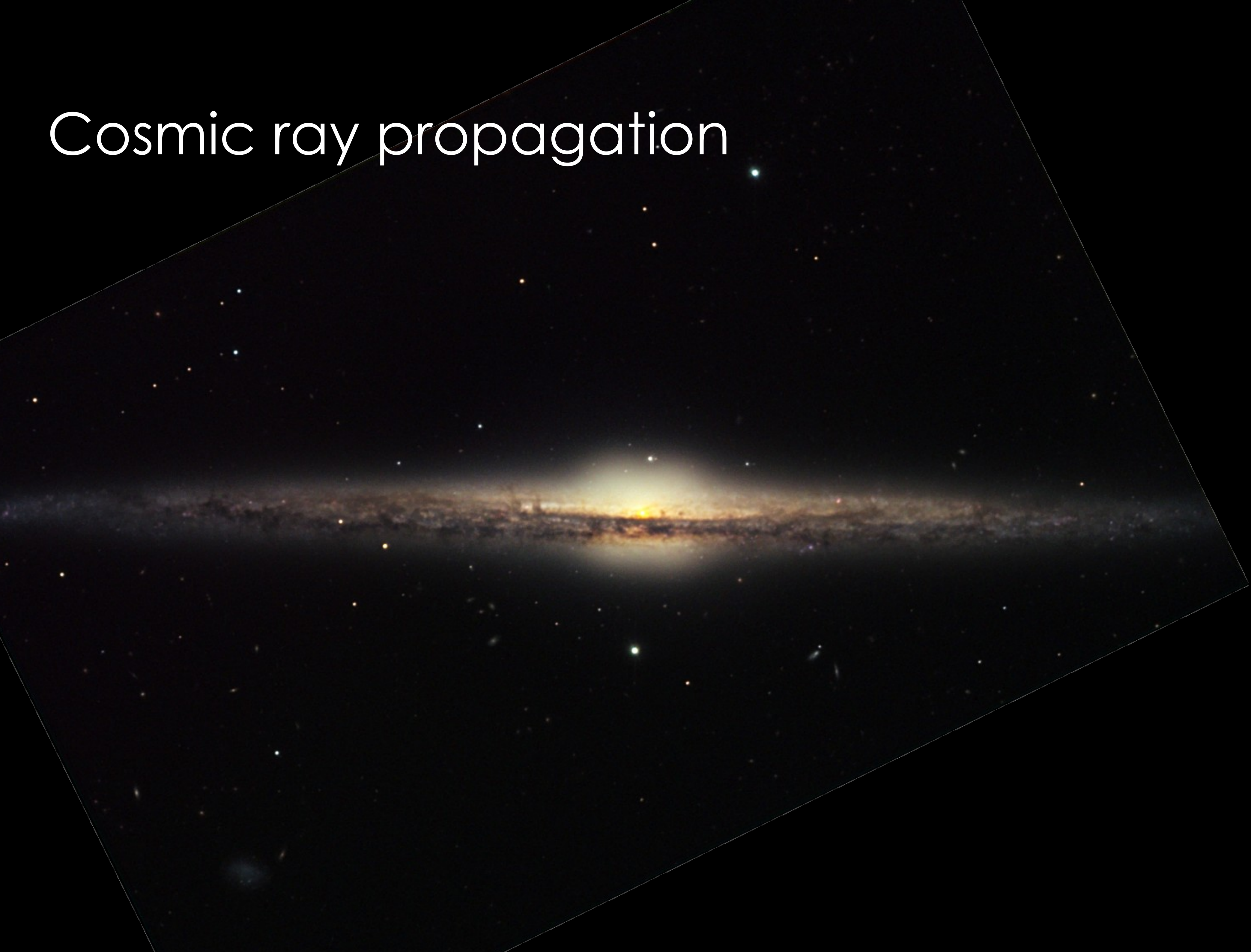
WIMP Searches



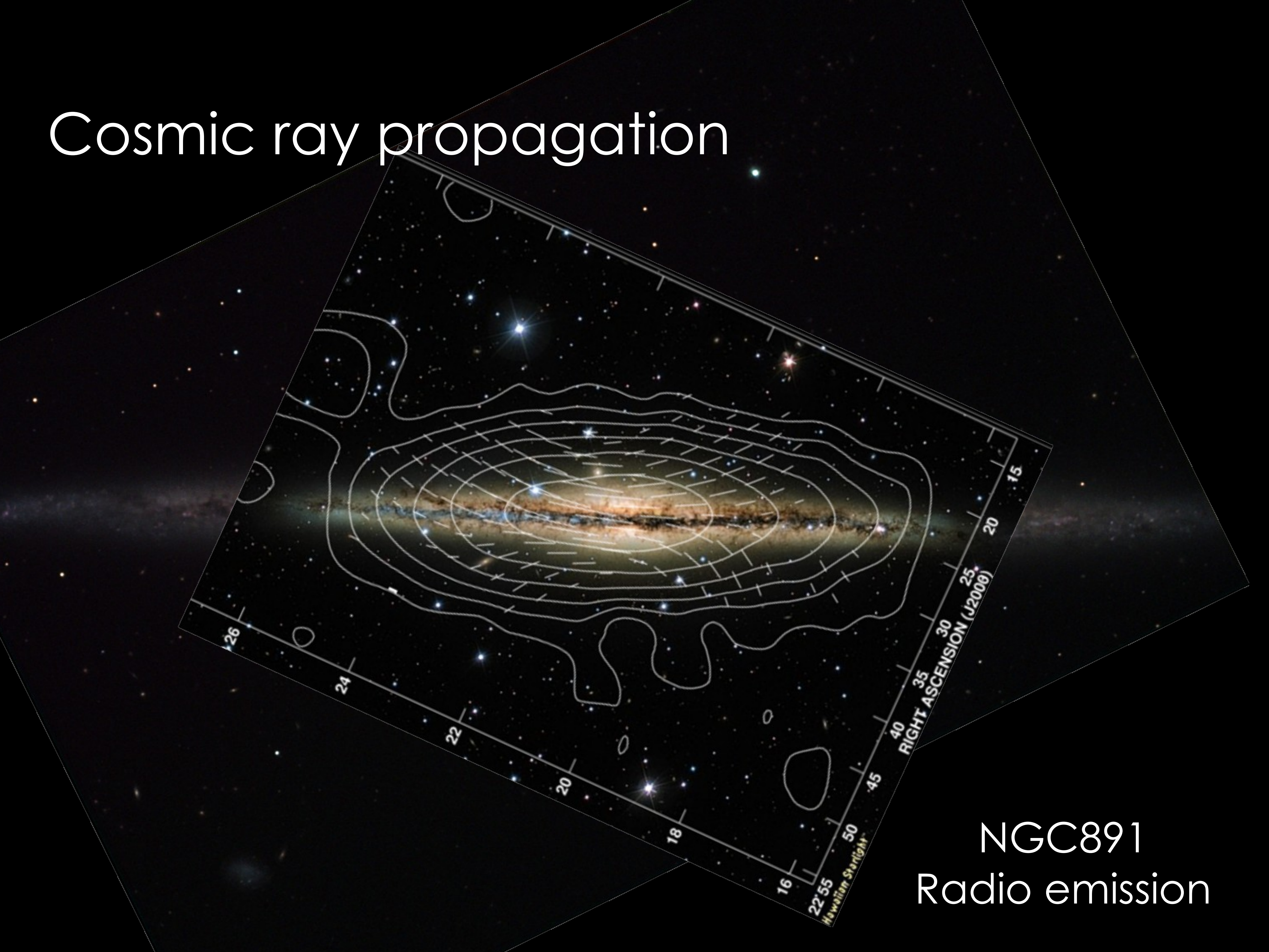
Indirect DM search



Cosmic ray propagation

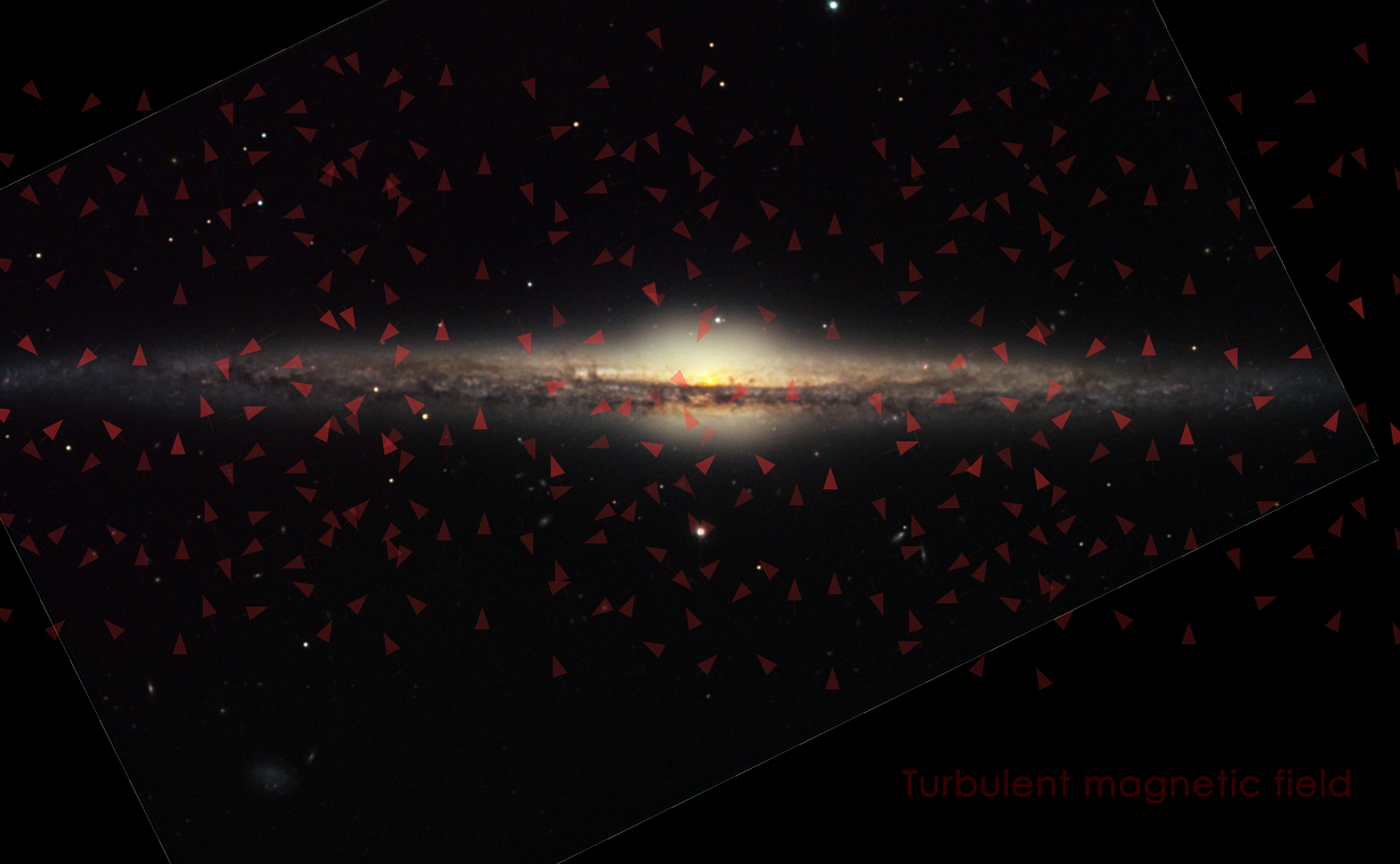


Cosmic ray propagation

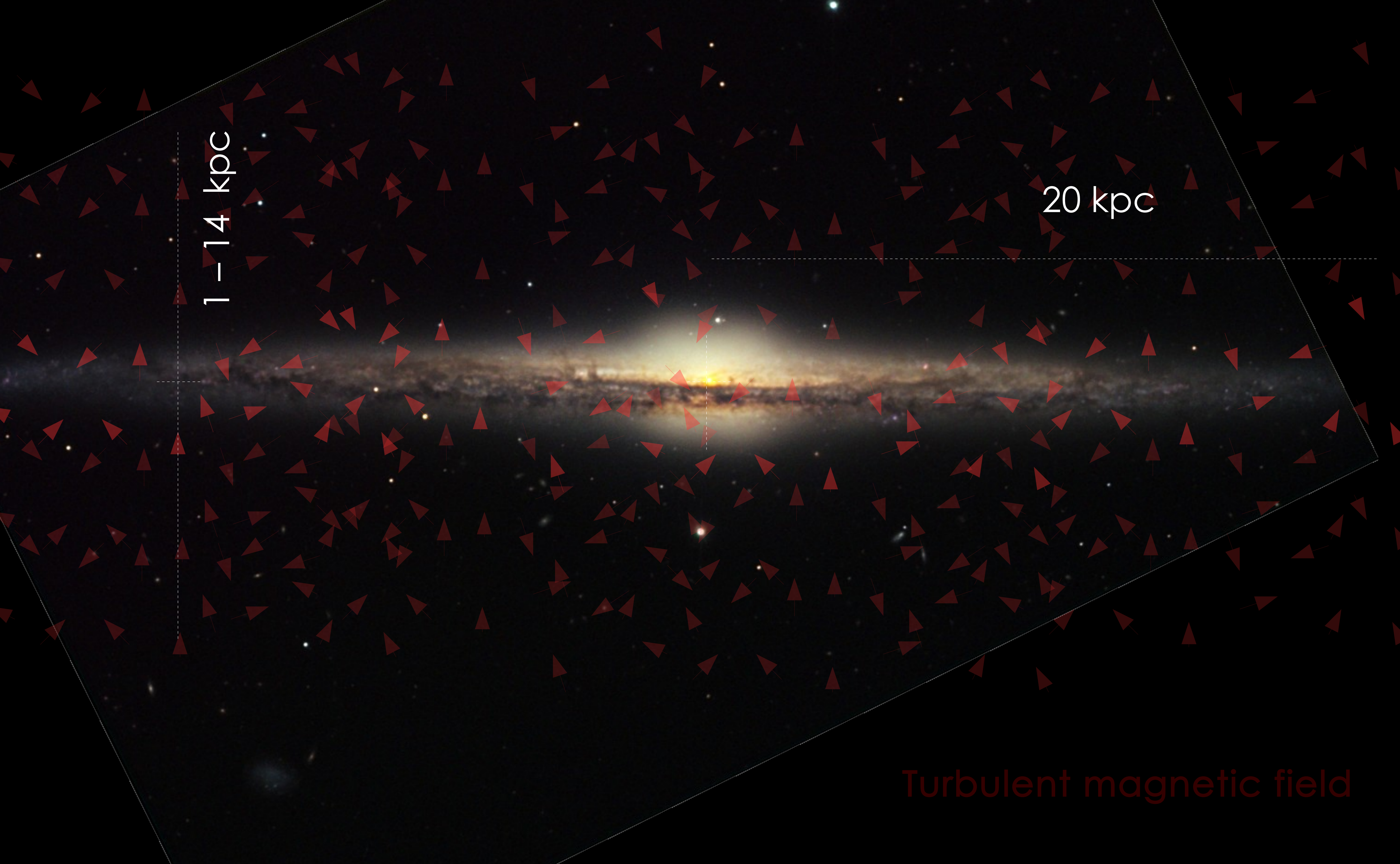


NGC891
Radio emission

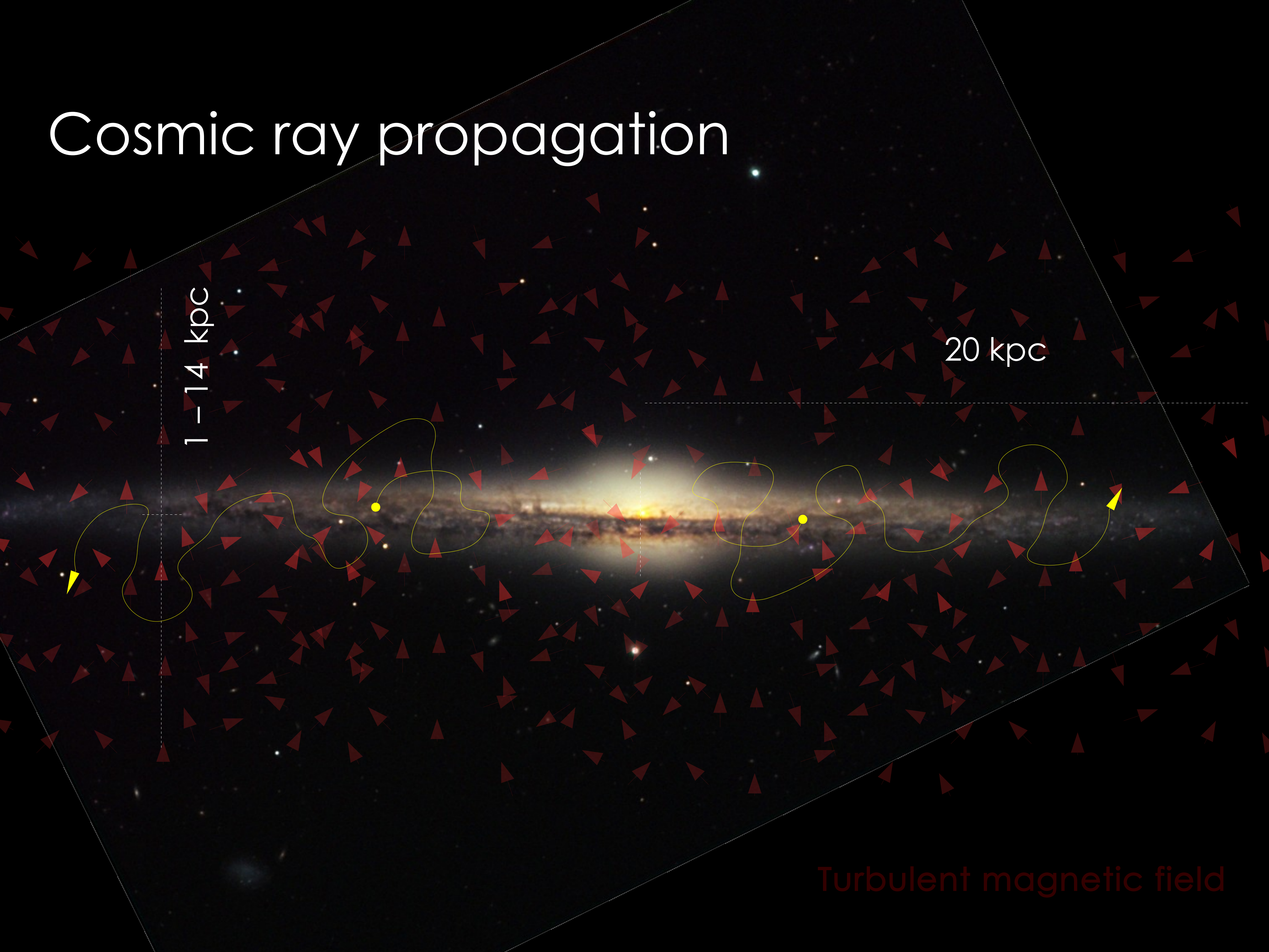
Cosmic ray propagation



Cosmic ray propagation



Cosmic ray propagation



Cosmic ray propagation

The transport equation describes the evolution of the density of cosmic rays

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^{\delta} \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_{\epsilon}}{\partial \epsilon} = q_{\mathrm{src}}$$

Time evolution

Diffusion

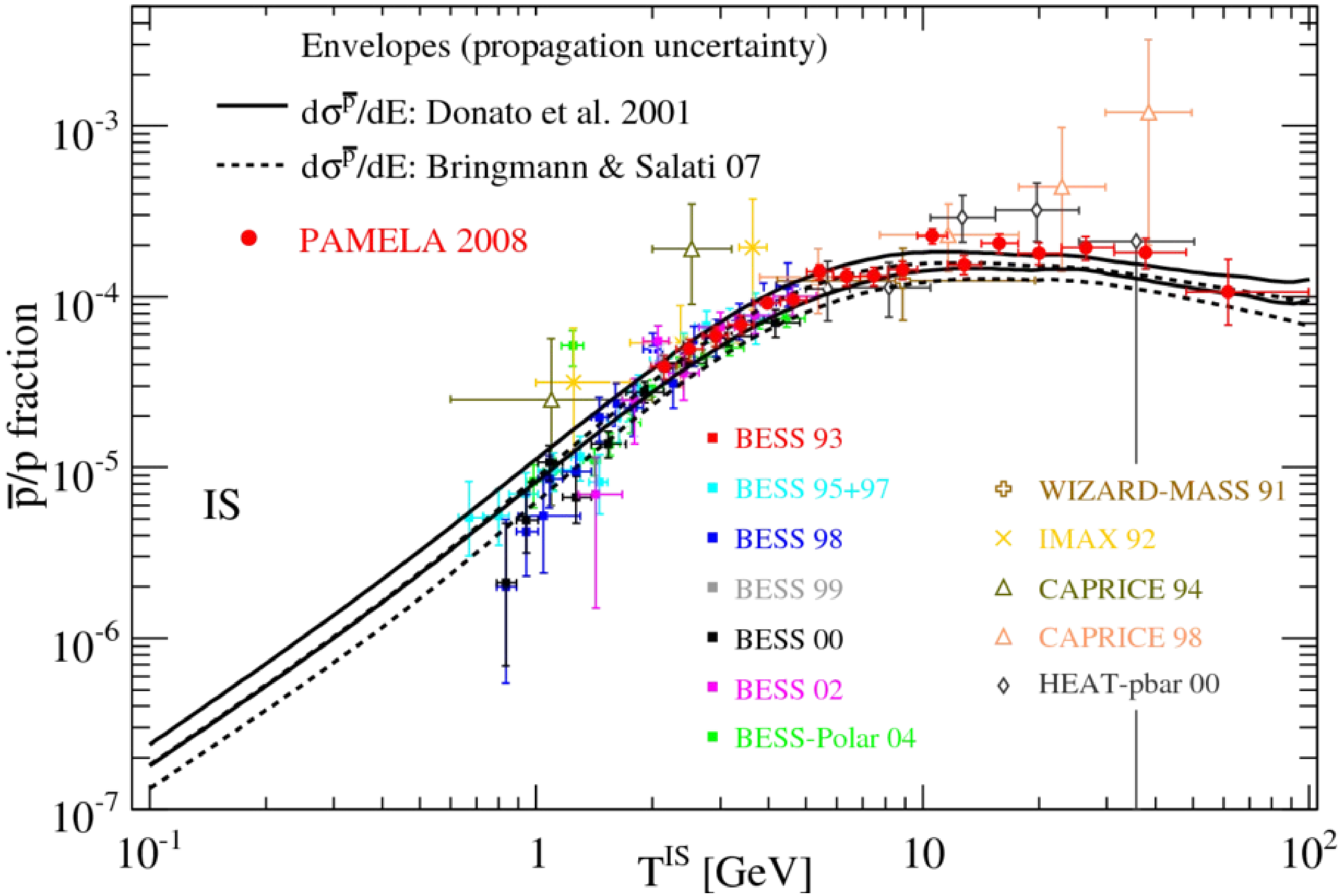
Convection

Energy evolution

Sources

Each specie has its own transport equation usually coupled with other CR specie

Cosmic ray propagation



Mod.	prop. parameters		
	L [kpc]	K_0 $\left[\frac{\text{kpc}^2}{\text{Myr}}\right]$	δ
min	1	0.0016	0.85
med	4	0.0112	0.70
max	15	0.0765	0.46

There is some degeneracy in the propagation's parameter space

Cosmic ray propagation

Transport equation

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^{\delta} \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\rm src}$$

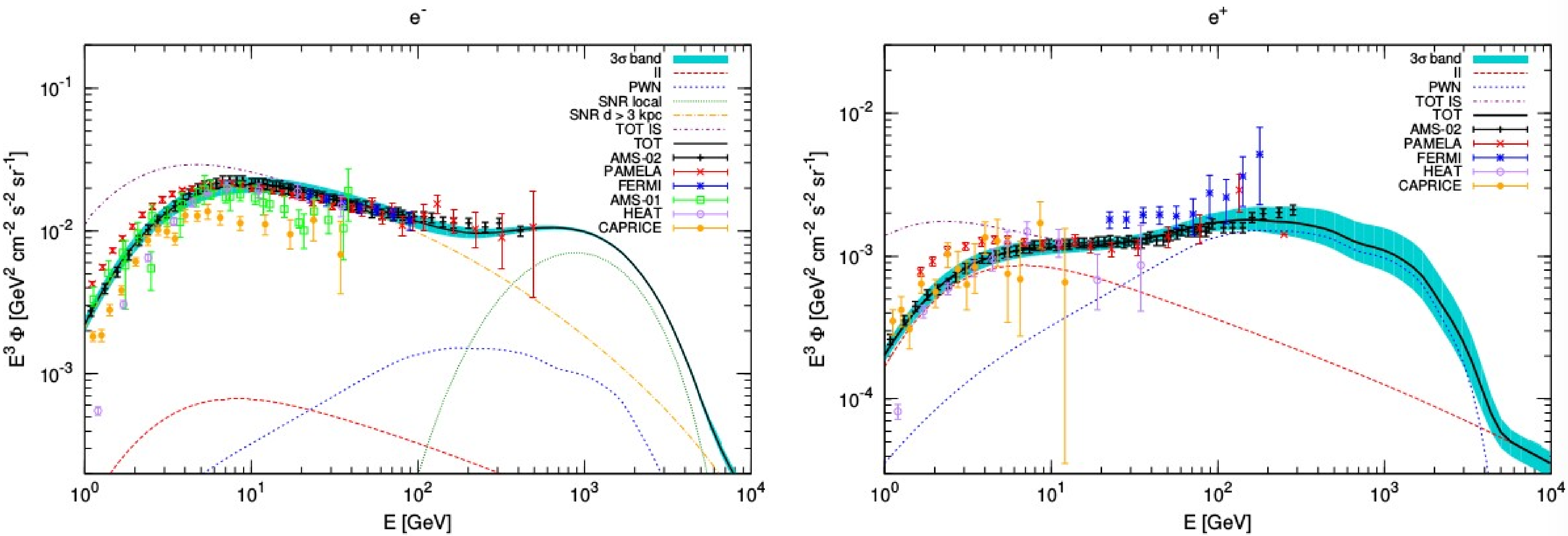
Secondaries
From spallations

$$q_{e^\pm}(\mathbf{x}, E_e) = 4\pi \, n_{\rm ISM}(\mathbf{x}) \int dE_{\rm CR} \Phi_{\rm CR}\left(\mathbf{x}, E_{\rm CR}\right) \frac{d\sigma}{dE_e}(E_{\rm CR}, E_e)$$

Primaries
From SNR and pulsars

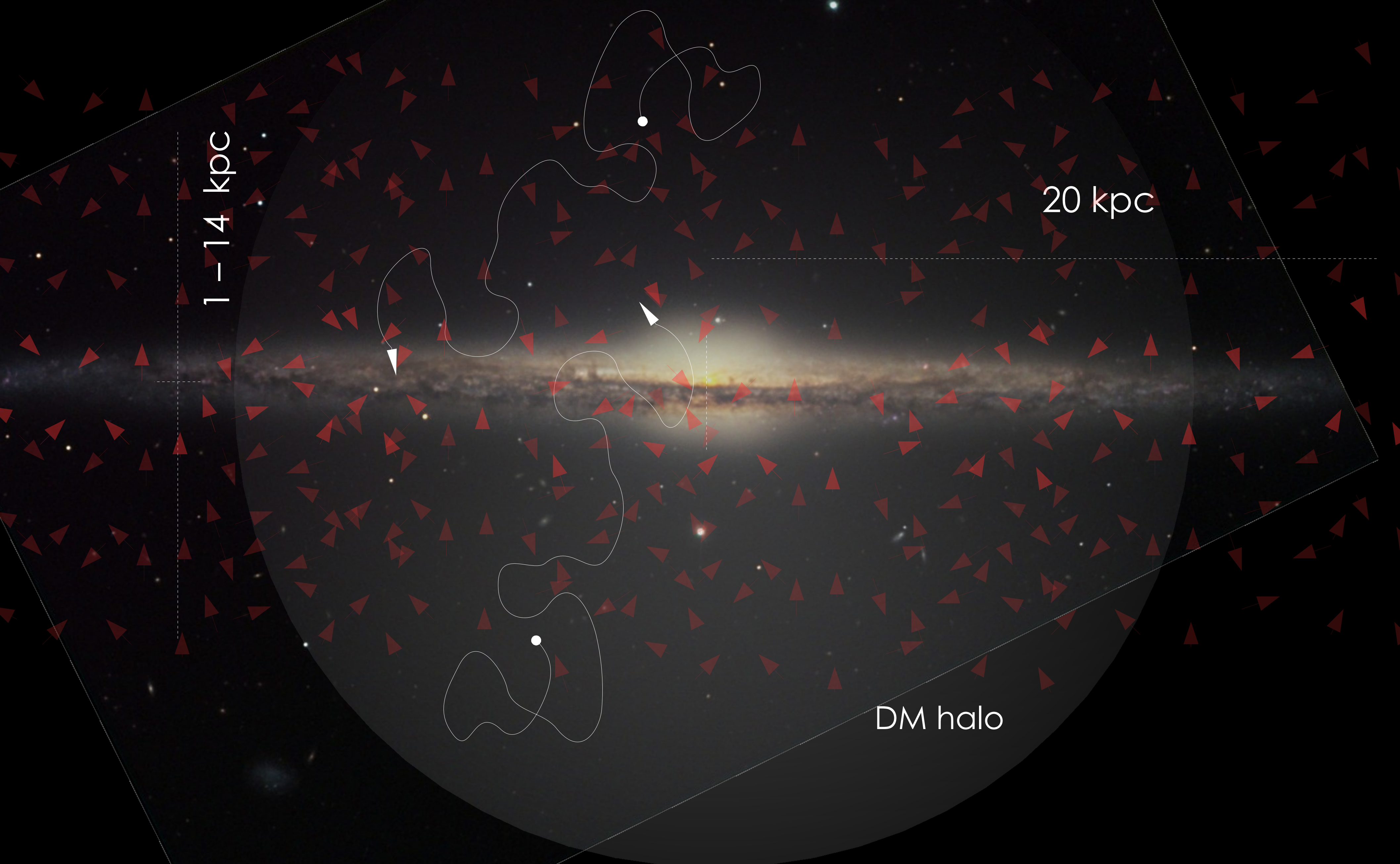
$$\begin{cases} \mathcal{Q}(E) = \mathcal{Q}_0 \epsilon^{-\gamma} \exp\left\{ -\frac{E}{E_c} \right\} \\ \rho(r, z) = \rho_0 \, r^a \, \exp\left\{ -\frac{r}{r_0} \right\} \exp\left\{ -\frac{|z|}{z_0} \right\} \end{cases}$$

Cosmic ray propagation



Details in arxiv:1402.0321

Cosmic ray propagation



Cosmic ray propagation

Transport equation

$$\frac{\partial \psi}{\partial t} + \nabla \cdot \left(-K_0 \epsilon^\delta \nabla \psi + \mathbf{V}_c \psi \right) + \frac{\partial J_\epsilon}{\partial \epsilon} = q_{\rm src}$$

Source from DM annihilation

$$q(\mathbf{x}, E) = \frac{1}{2} (\sigma v) \left(\frac{\rho(\mathbf{x})}{M_{\rm DM}} \right)^2 \frac{dn}{dE}(E)$$

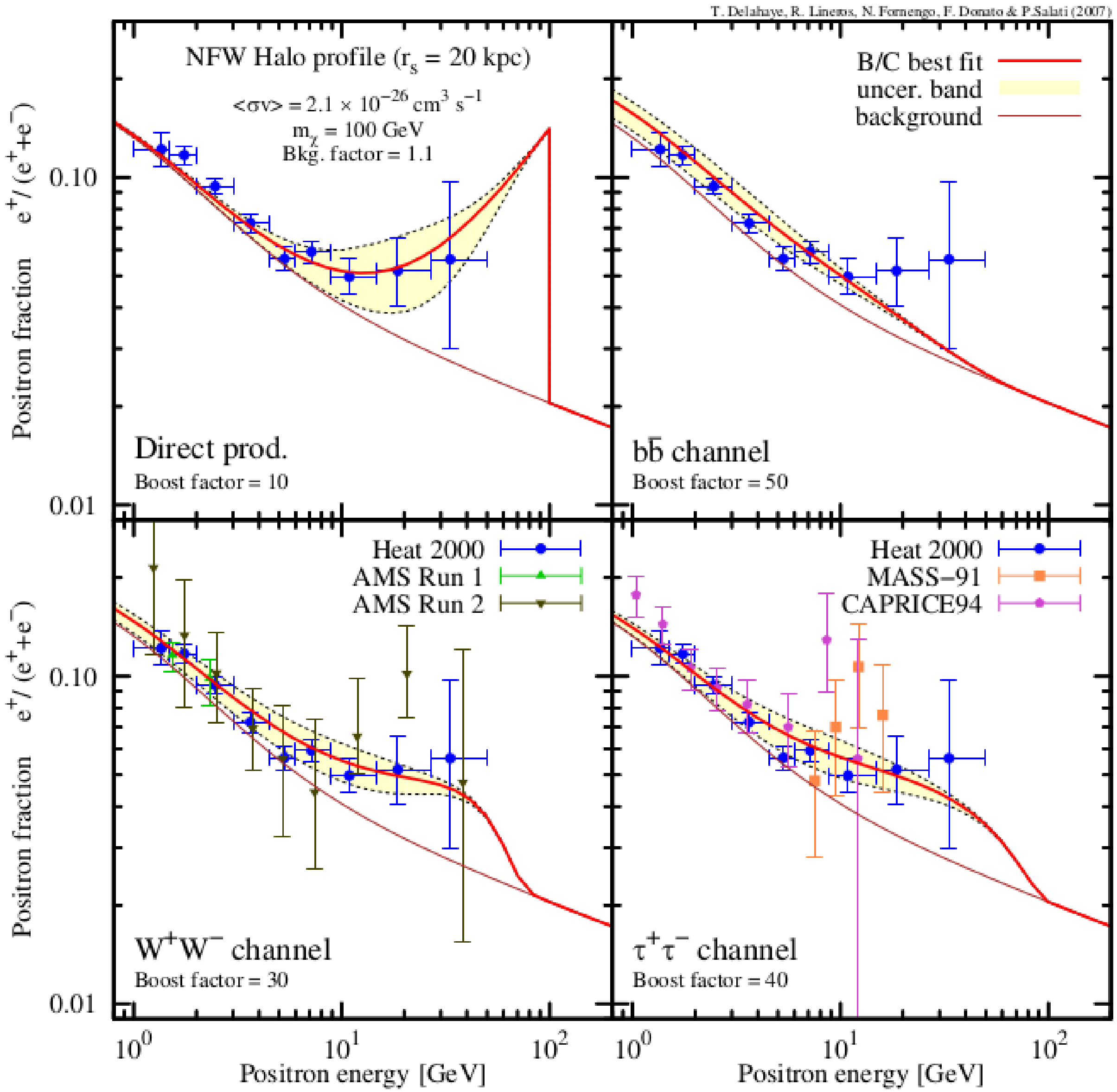
Annihilation cross section

Annihilation spectrum

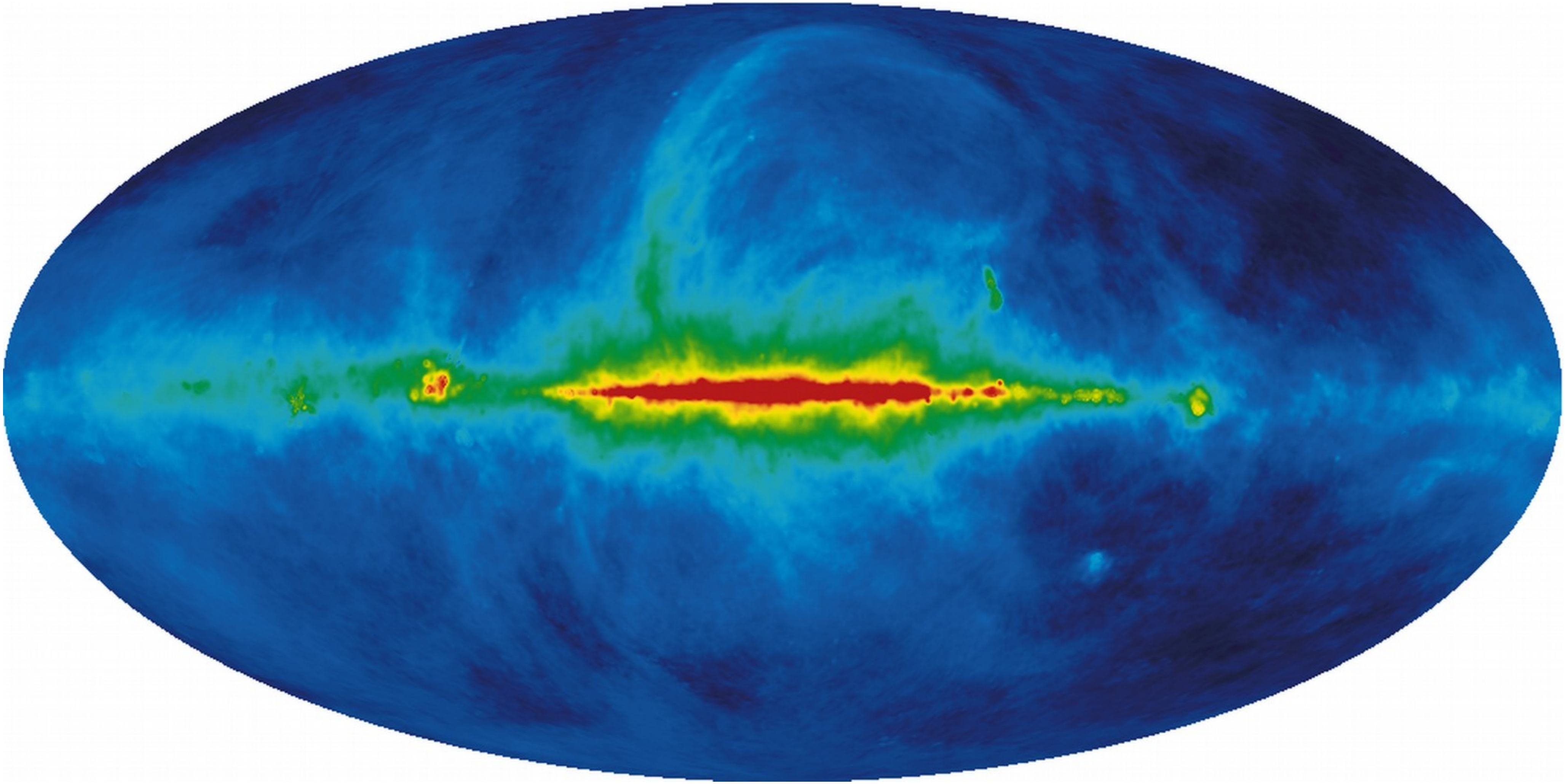
DM distribution

Cosmic rays propagation

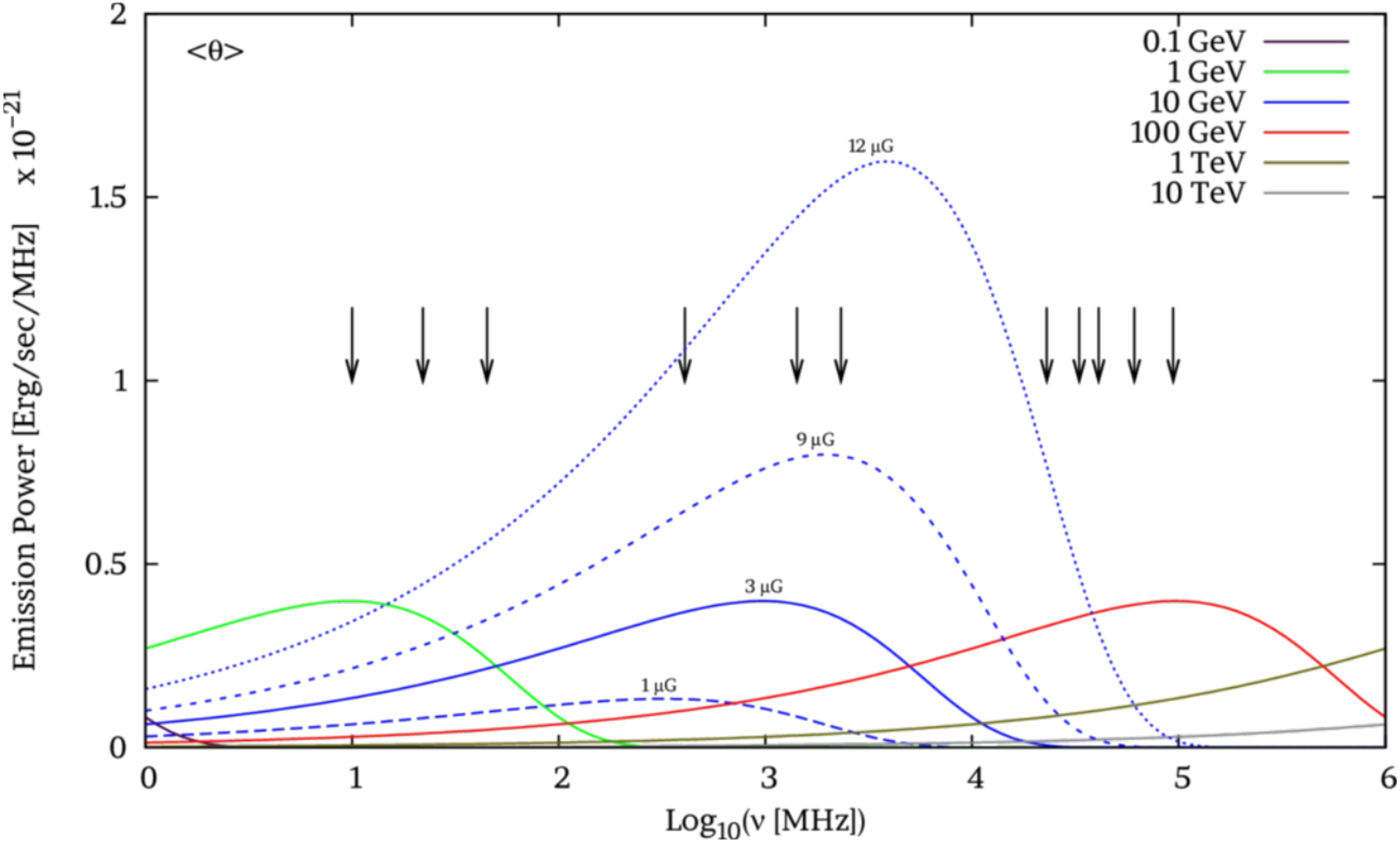
[arxiv:0712.2312]



WIMP Searches in radio



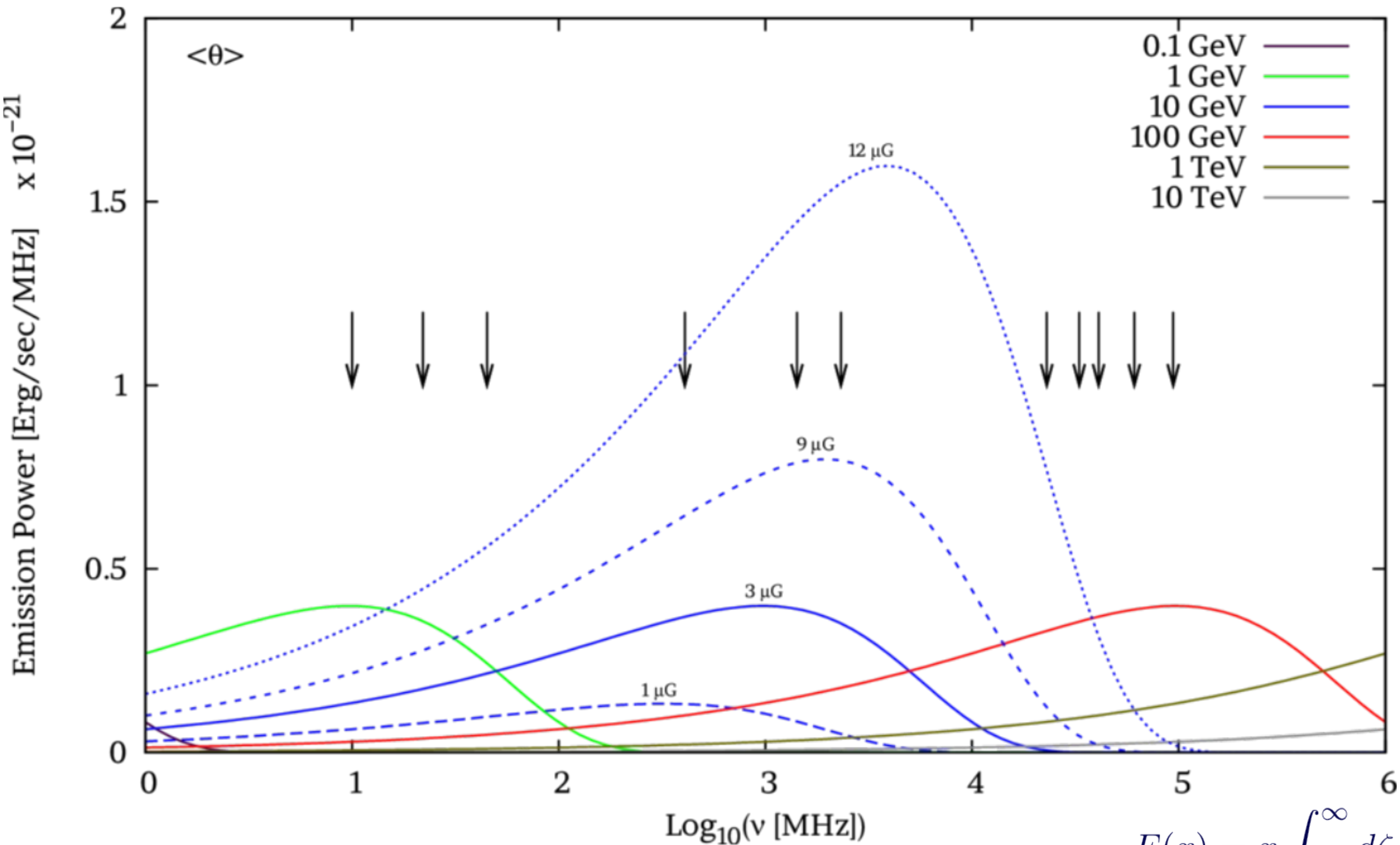
Synchrotron spectrum



Synchrotron spectrum

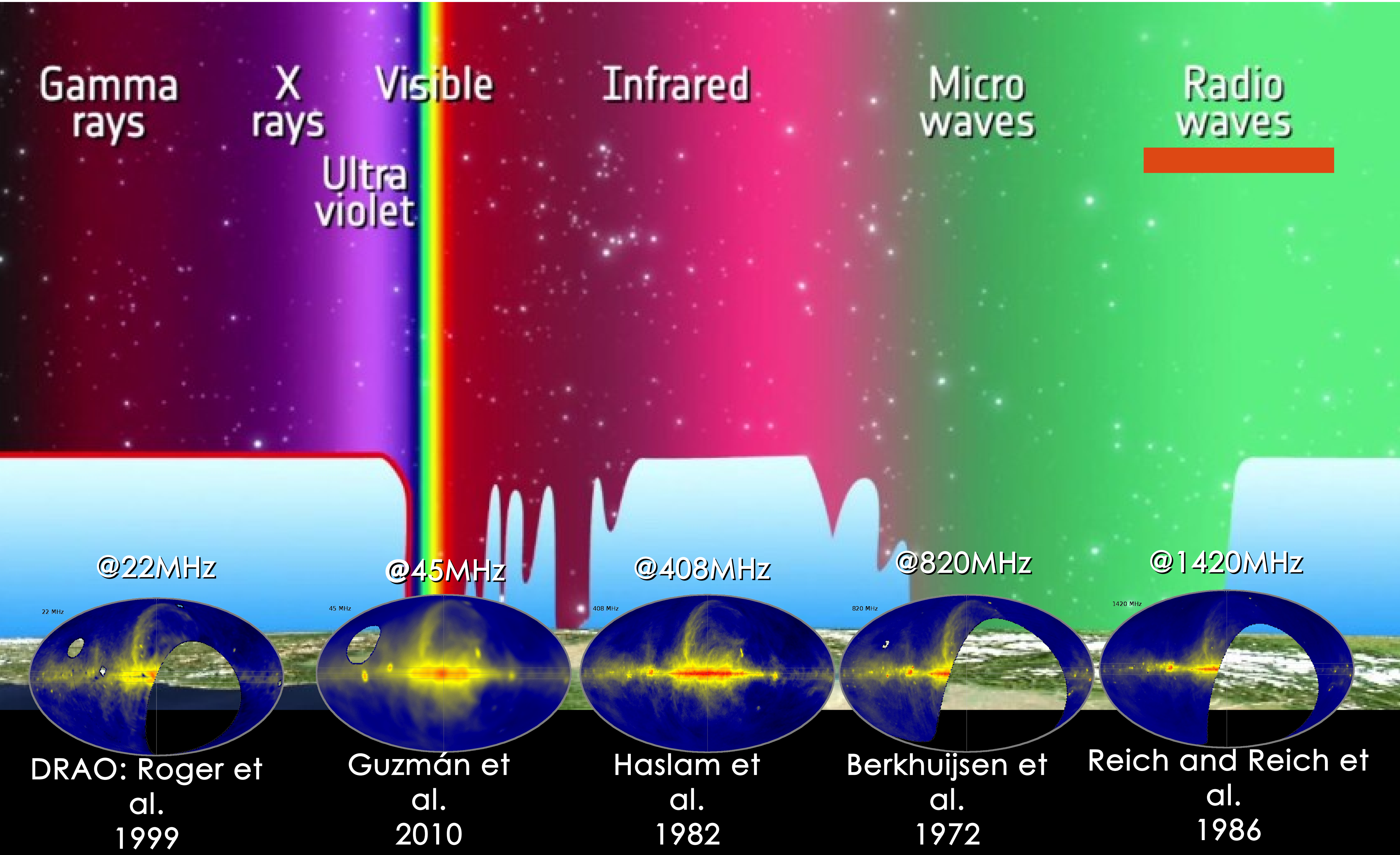
$$\frac{dw}{d\nu}(\nu, B_\perp) = \frac{\sqrt{3}\, e^3 B_\perp}{m_e c^2} F\left(\frac{\nu}{\nu_{c,\perp}}\right)$$

$$\nu_{c,\perp} = \frac{3 e B_\perp E^2}{4\pi m_e^3 c^5}$$

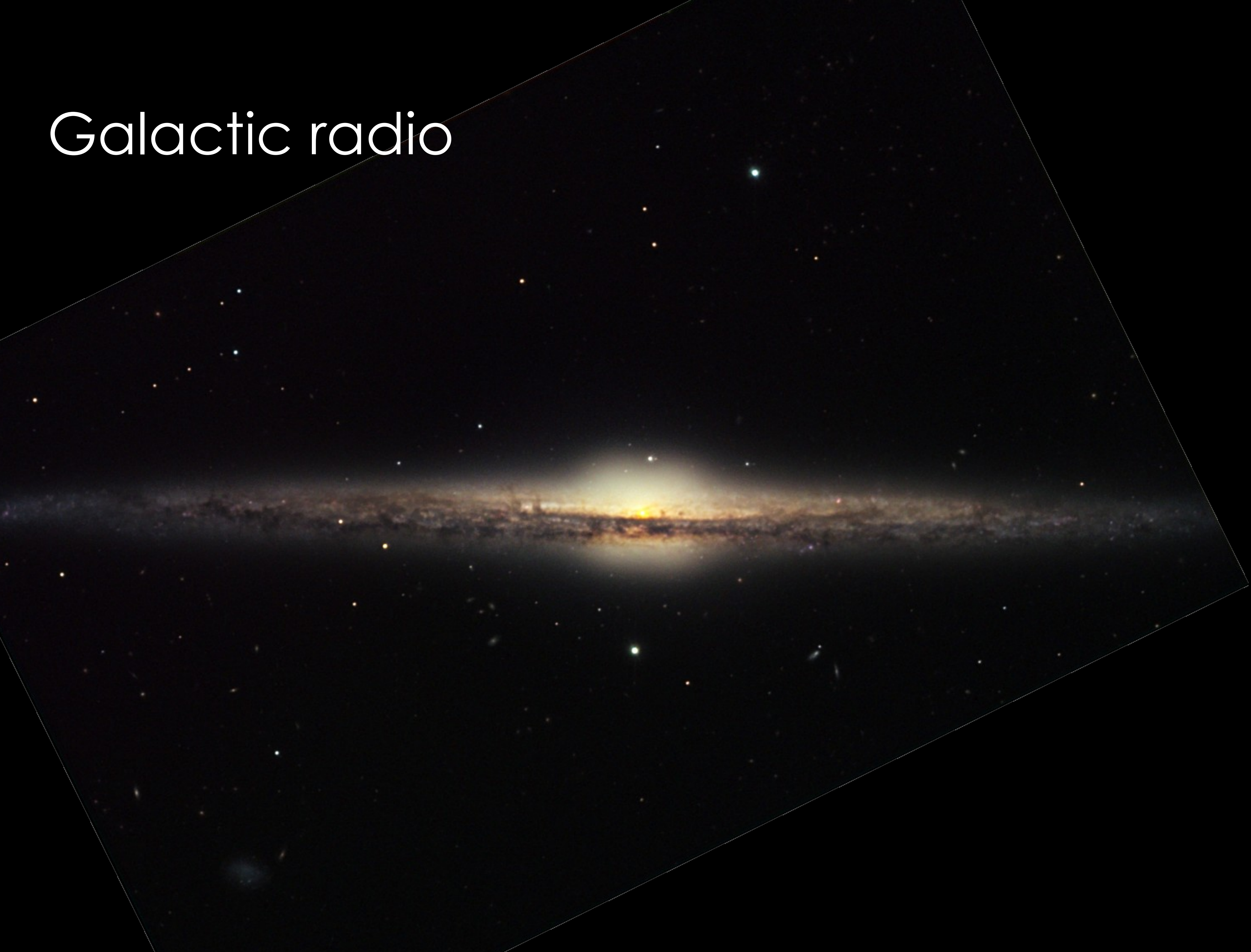


$$F(x) = x \int_x^\infty d\zeta\; K_{5/3}(\zeta)$$

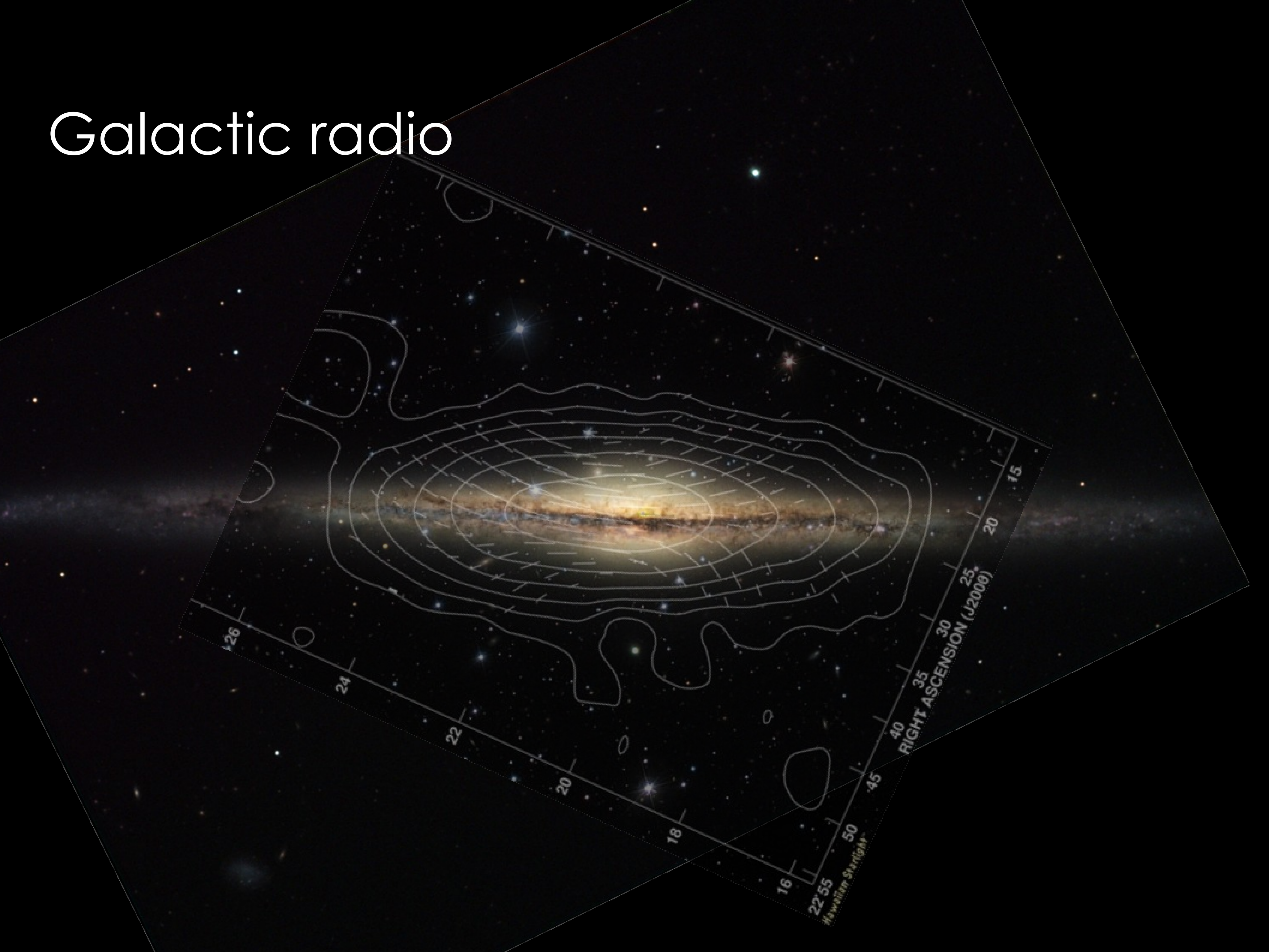
Observations from 22 to 1420 MHz



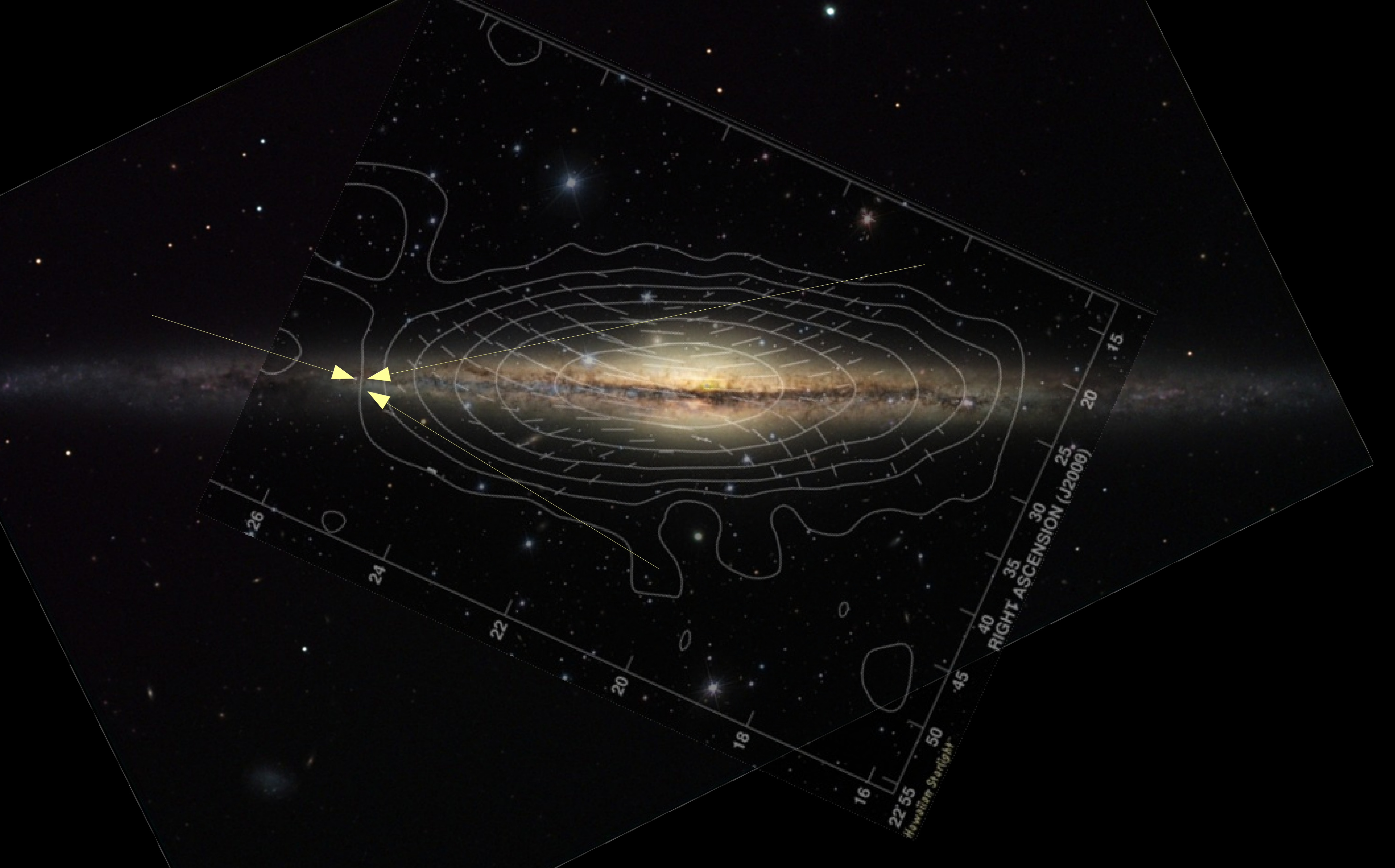
Galactic radio



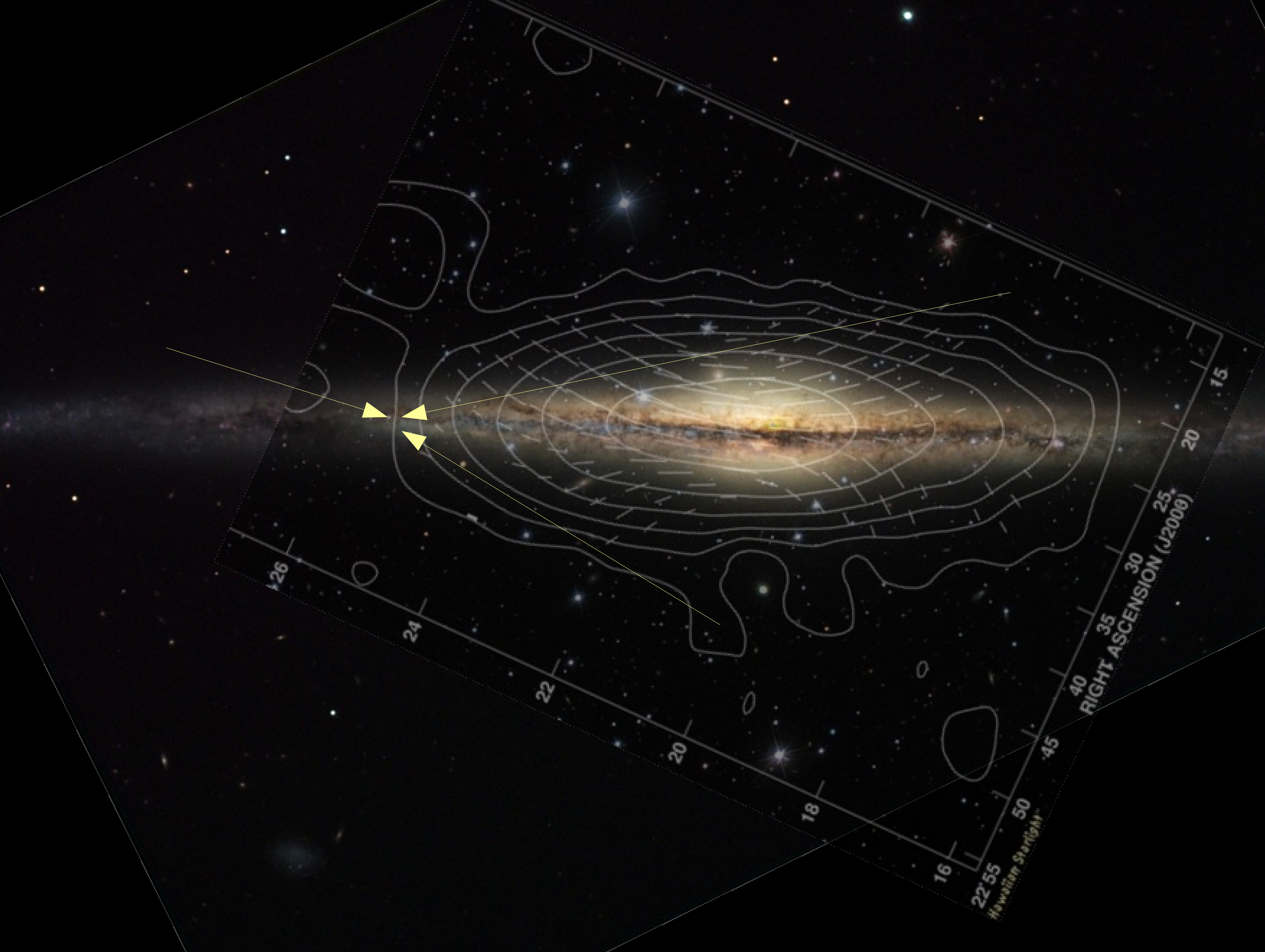
Galactic radio

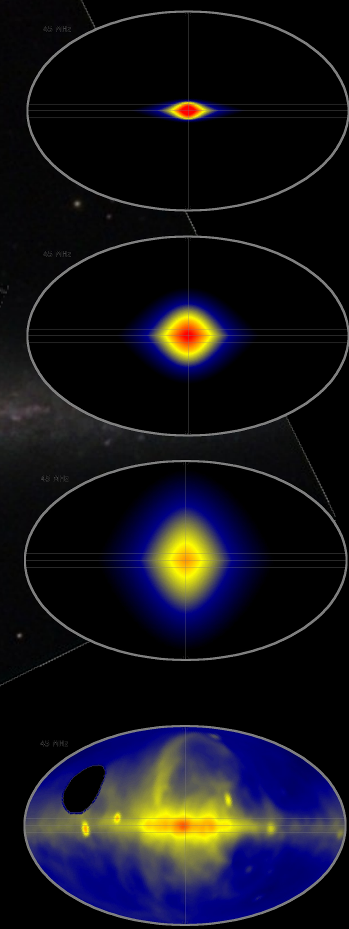


Galactic radio

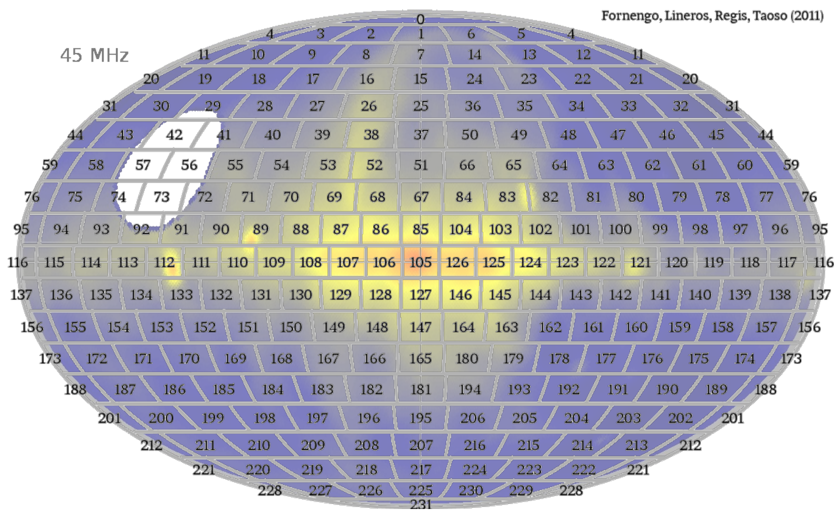


Galactic radio



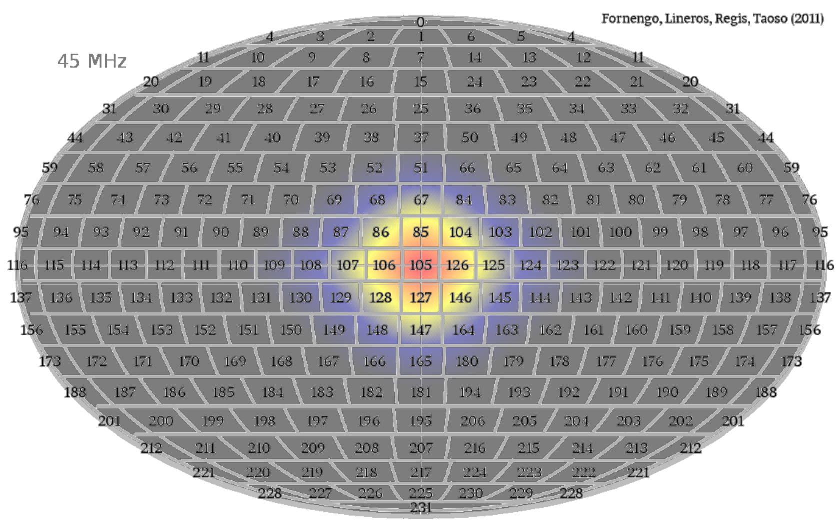


Constraining Galactic DM



We divide Obs & DM skymaps into several patches ~10^0x10^0

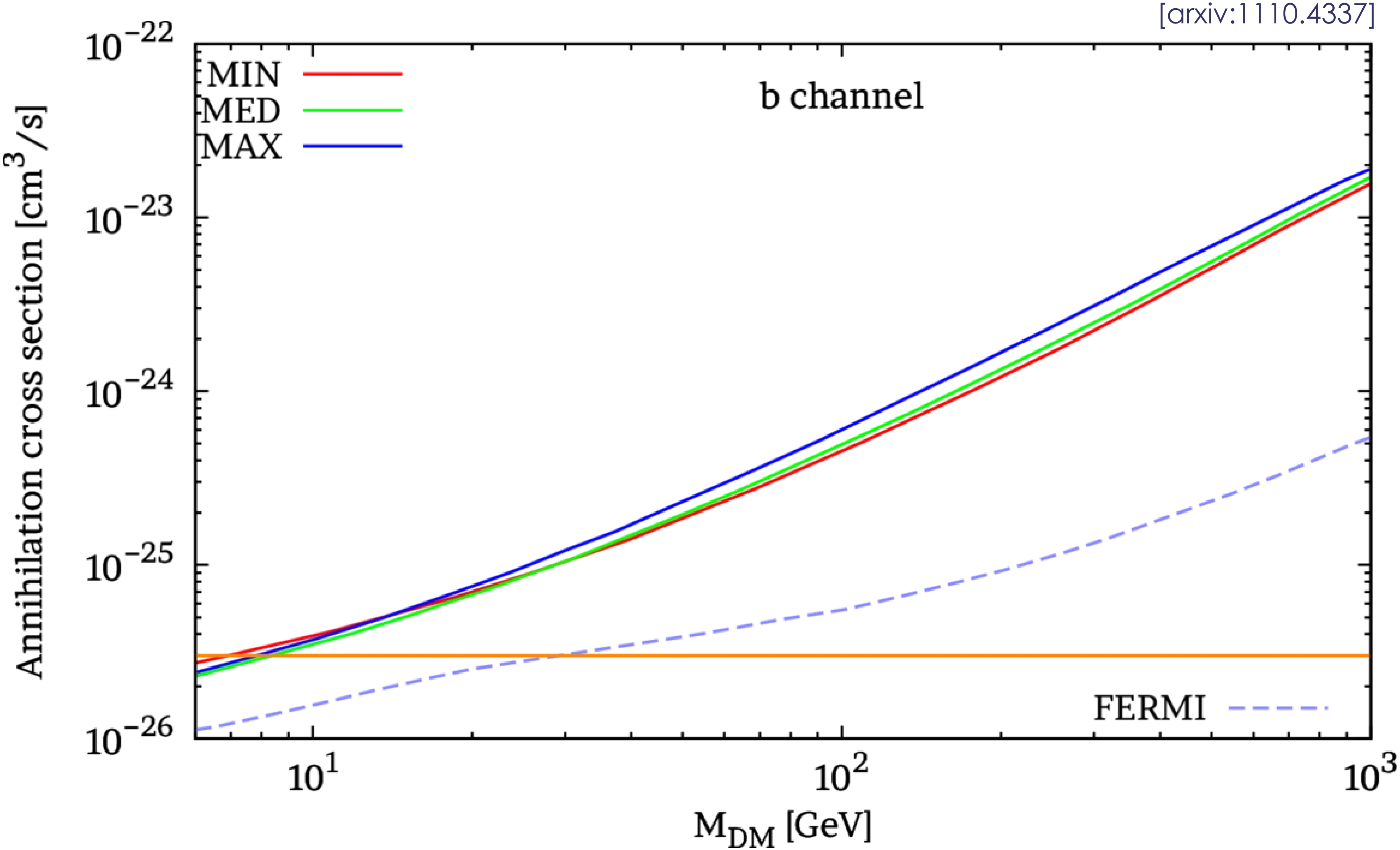
$$T_{\rm DM} \leq T_{\rm obs} + 3\sigma$$



We calculate an upper bound for (σv) using the most stringent patch in each skymap

Annihilation into b quarks

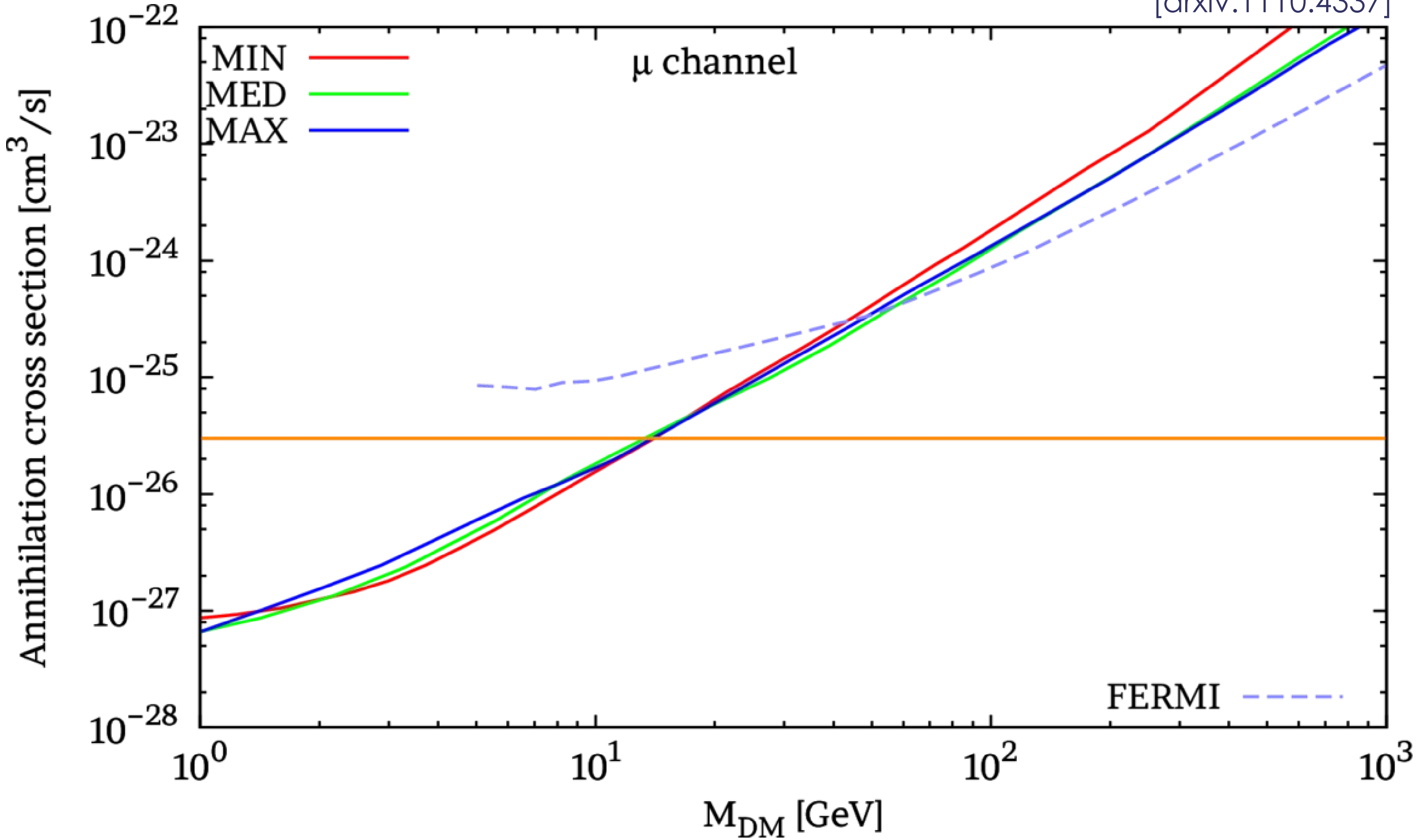
[arxiv:1110.4337]



Thermal cross section is reached at ~10 GeV

Annihilation into muons

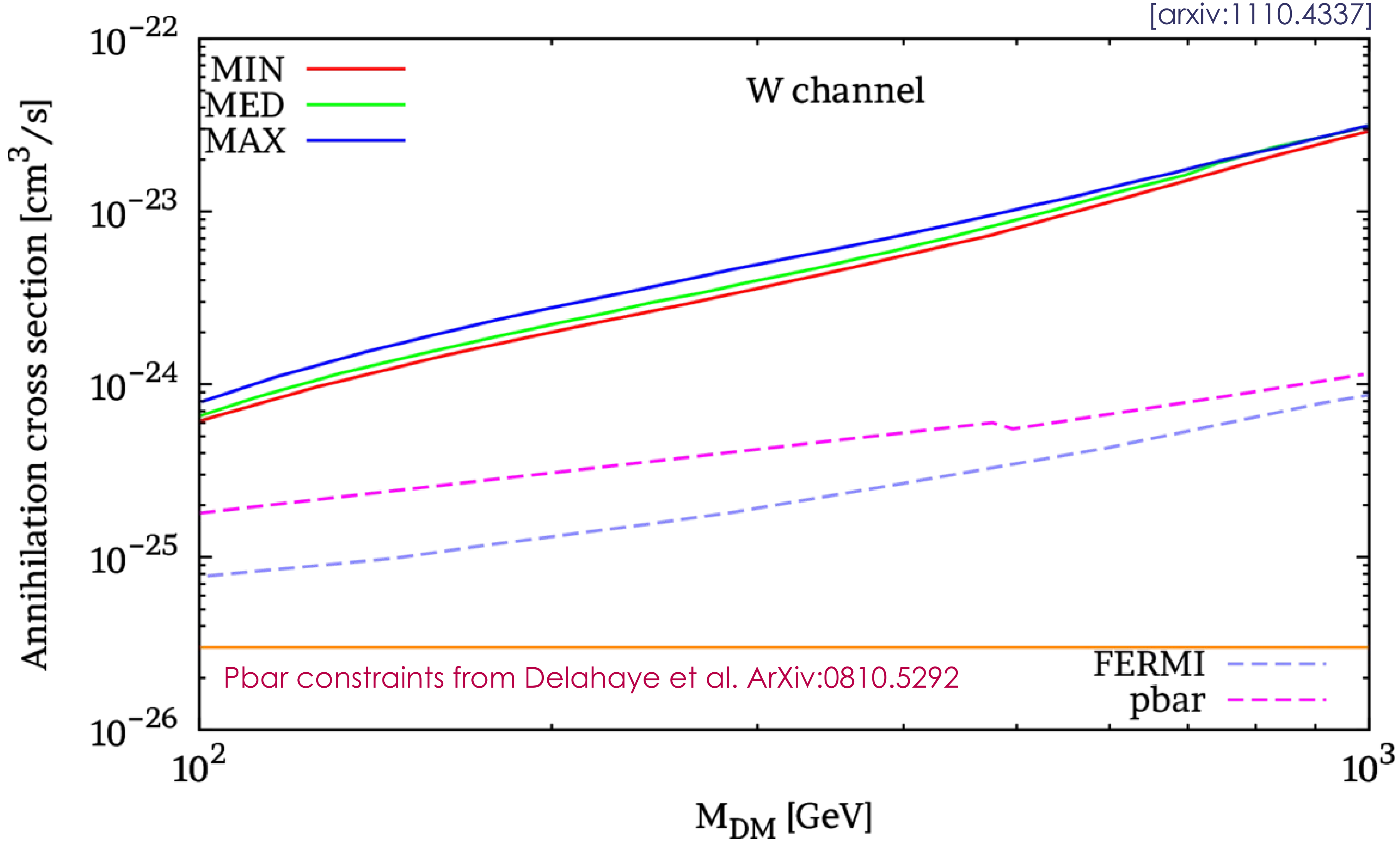
[arxiv:1110.4337]



Constraints for DM lighter than ~15 GeV

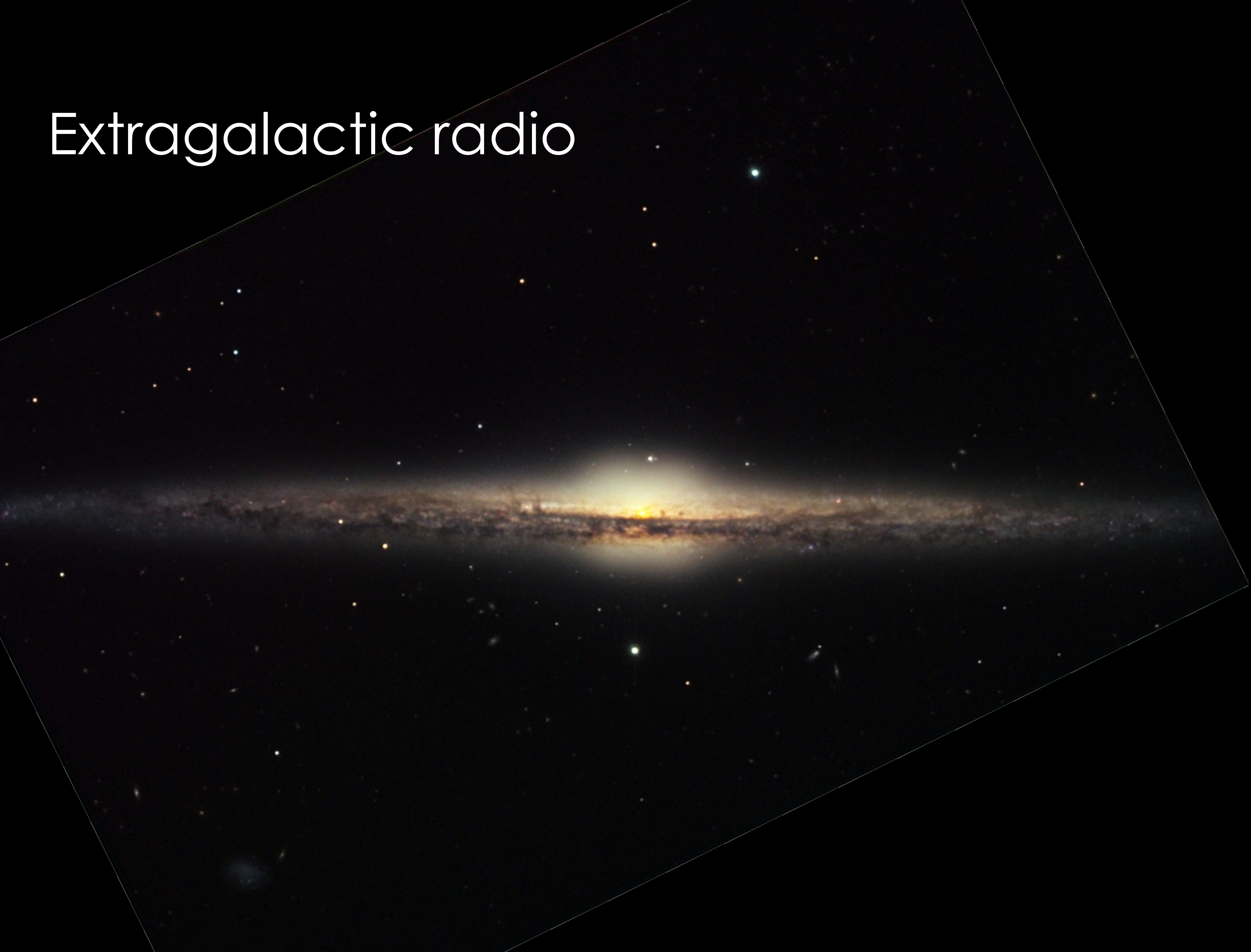
Annihilation into W bosons

[arxiv:1110.4337]

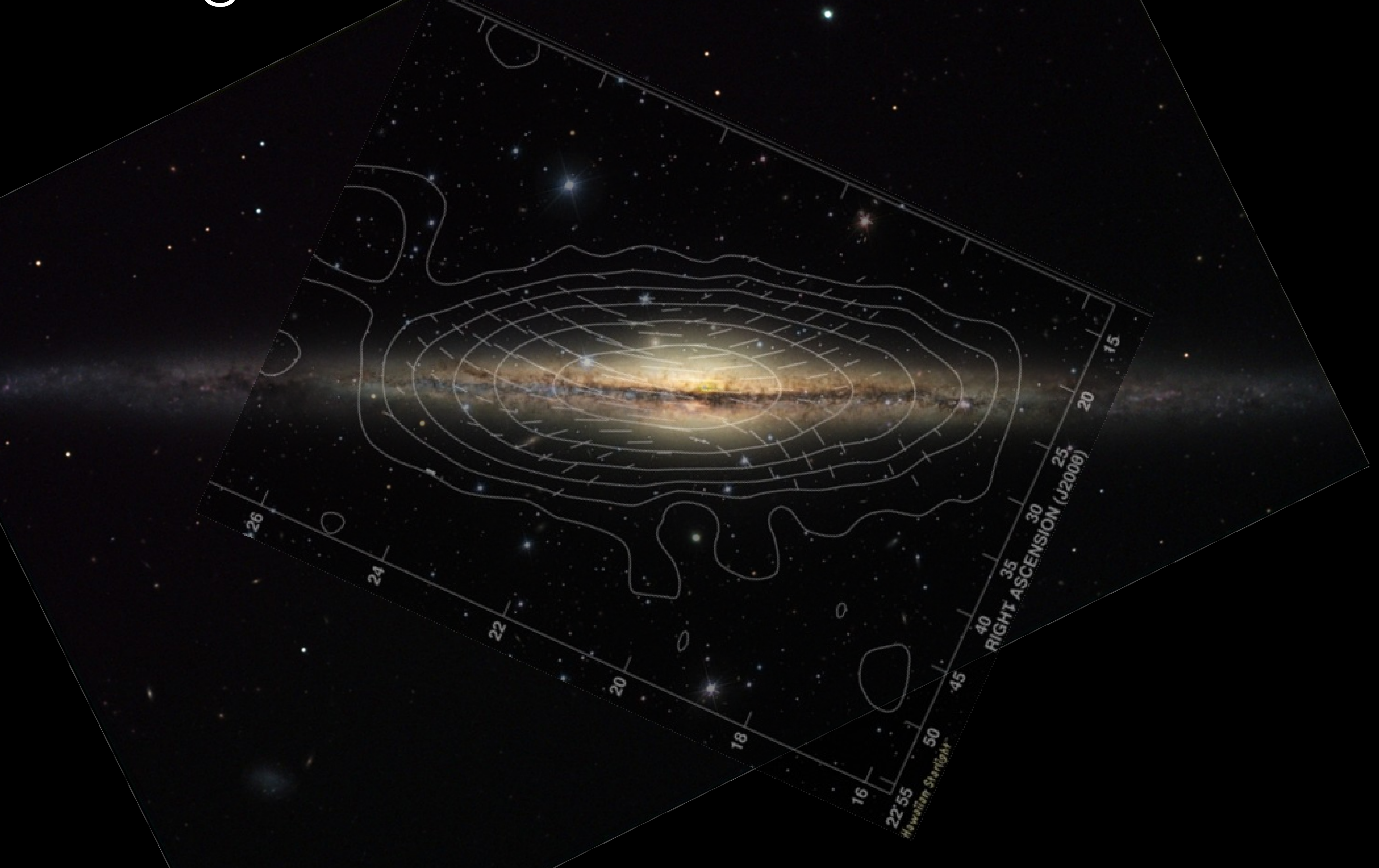


Bounds for W bosons are not so strong

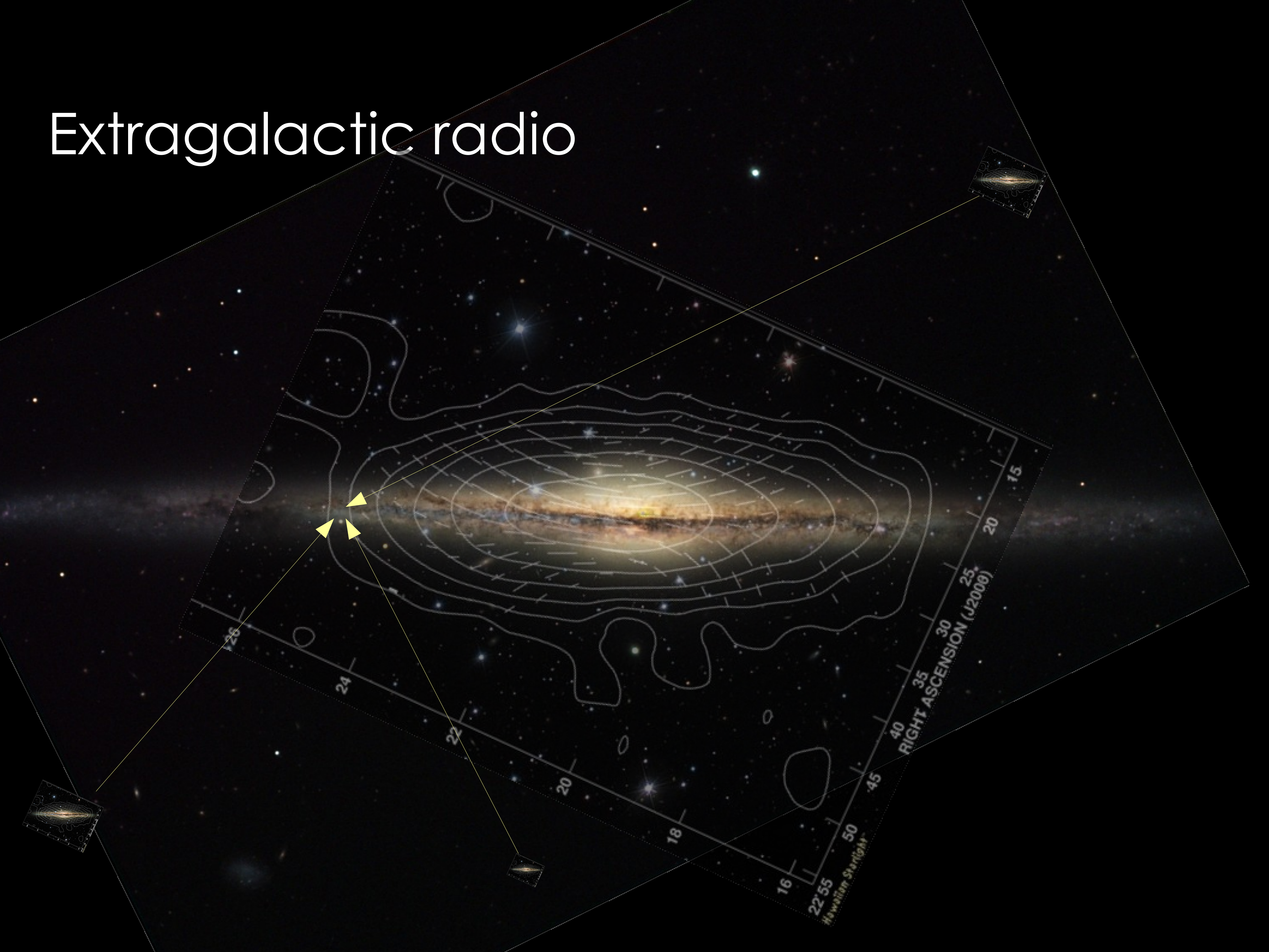
Extragalactic radio



Extragalactic radio

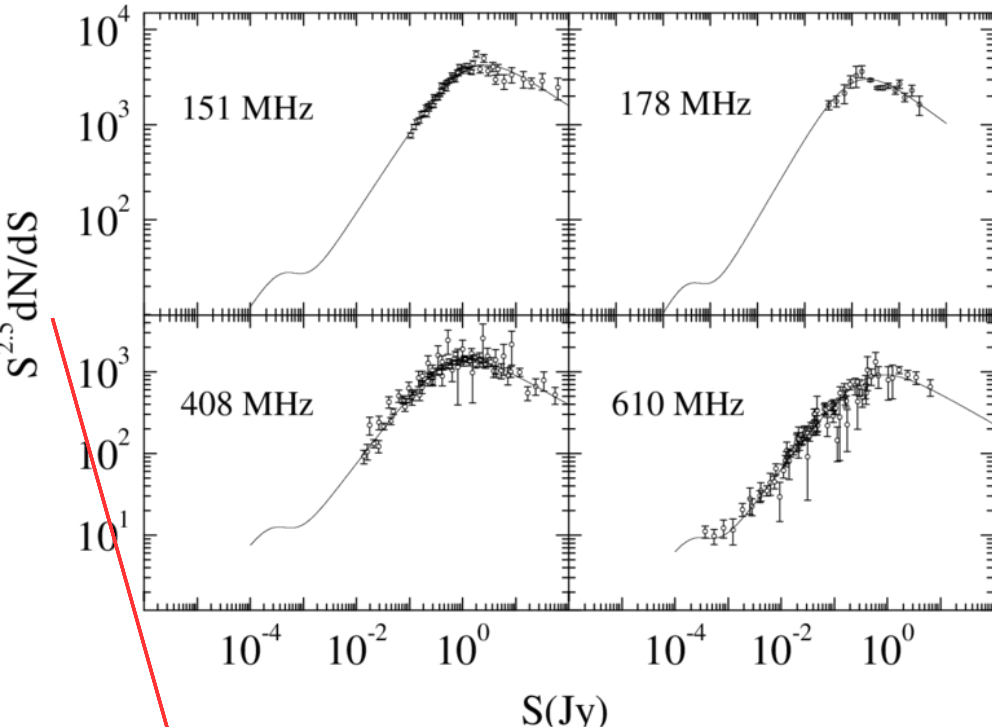


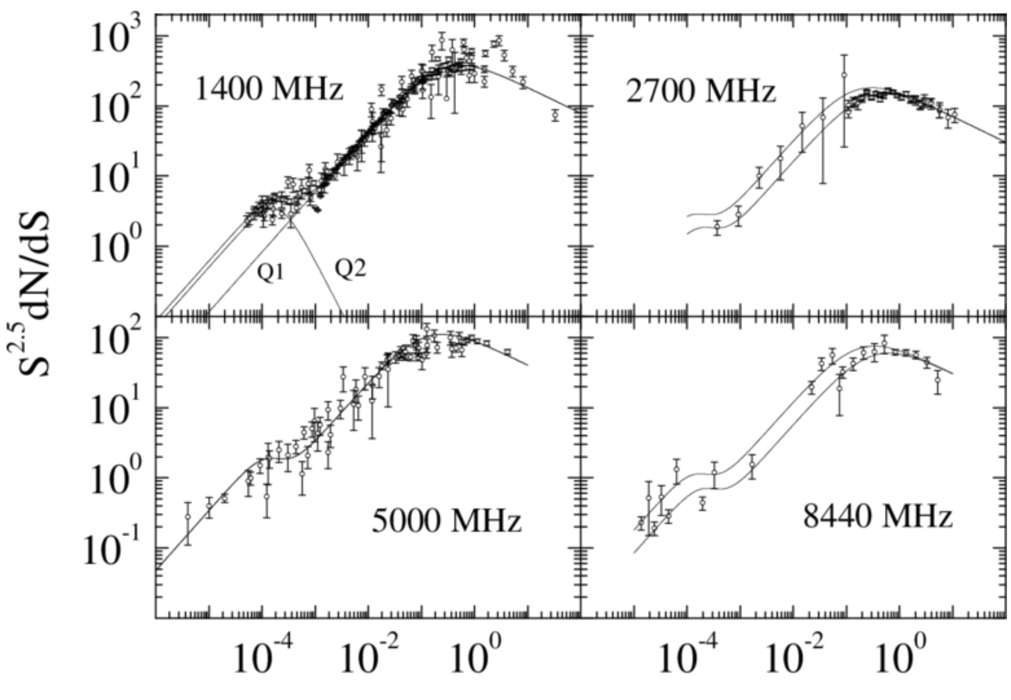
Extragalactic radio



Source Count

Gervasi et al. 0803.4138





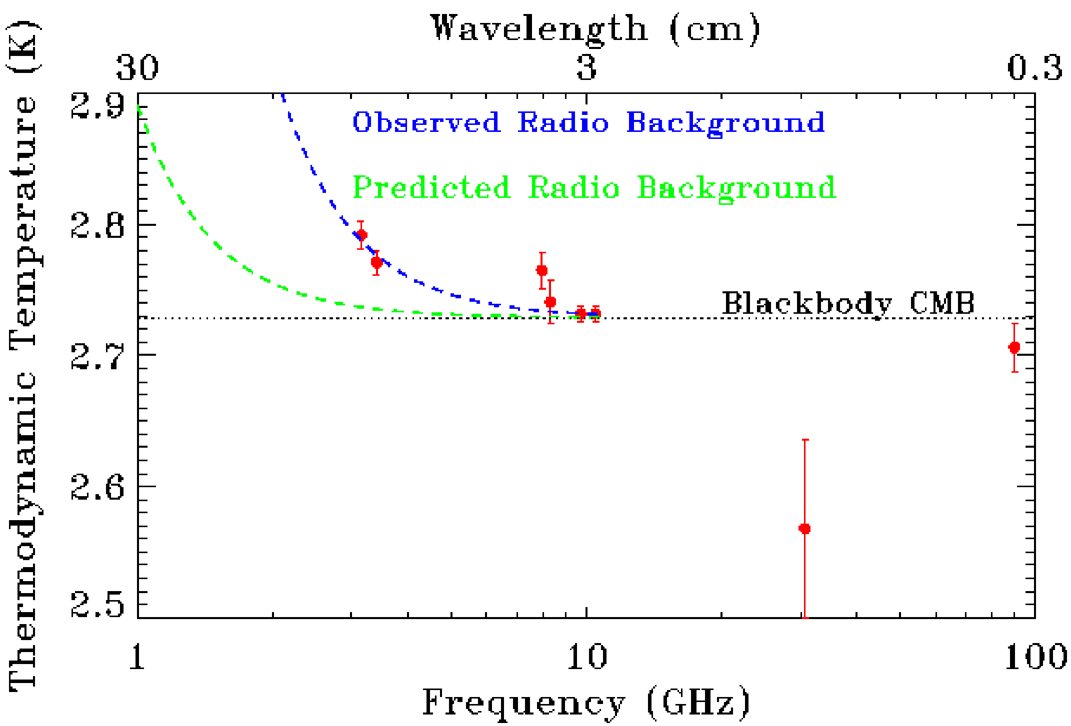
Sources per:
unit angle
unit of intensity

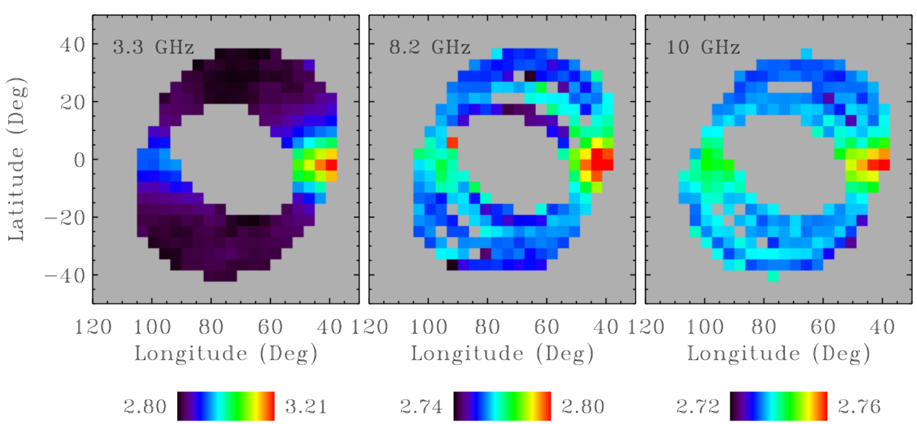
$$\frac{dN}{dS}(S)\, S\, dS = \frac{2\, k_B}{c^2}\, \nu_{\rm obs}^2\, dT$$

$$T_E = \int dT = \frac{c^2}{2\, k_B\, \nu_{obs}^2} \int_0^{S_{\rm max}} dS\, \frac{dN}{dS}(S)\, S$$

Isotropic radio background

ARCADE 2 anomaly





They have reported an excess in the radio background which is bigger that the expected with known sources

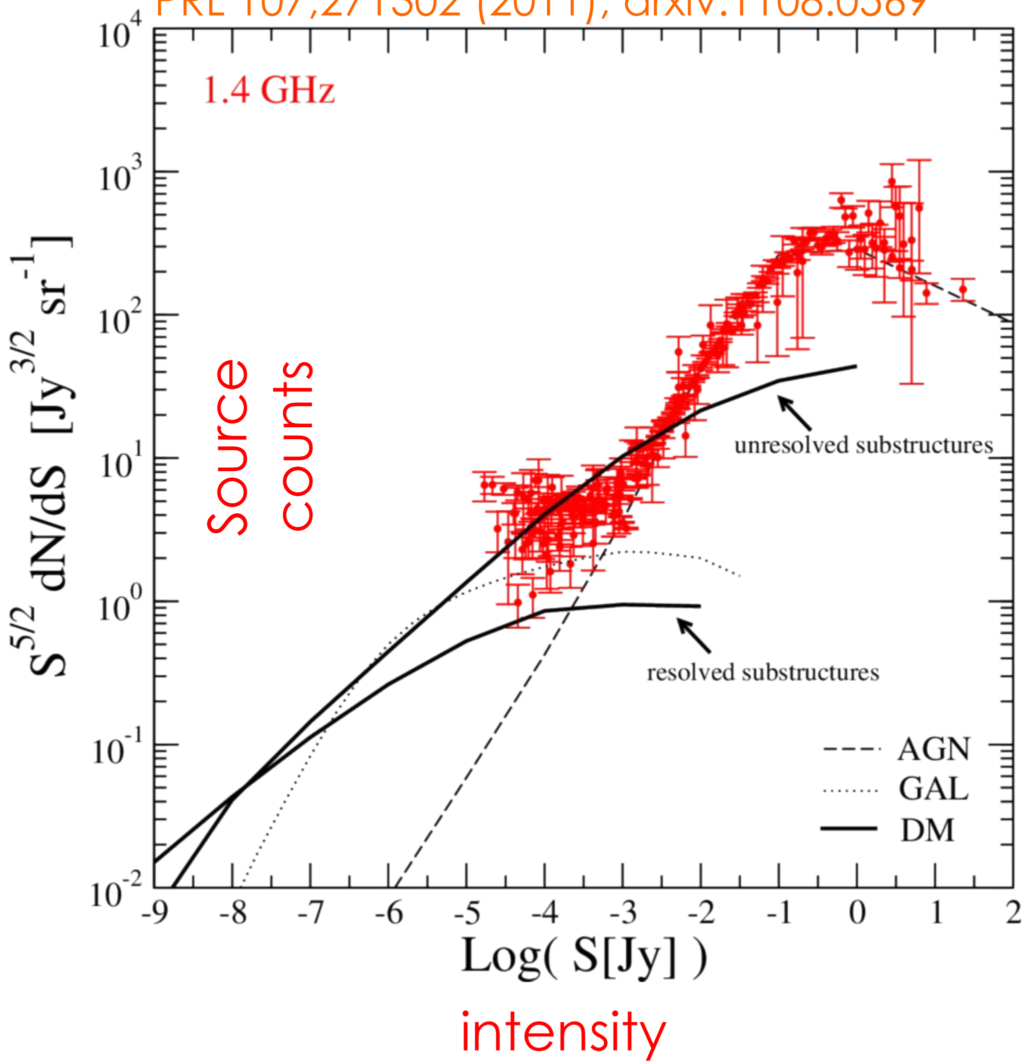
$$T_{sky}(\nu, \alpha, \delta) = T_{cmb}(\nu) + T_{gal}(\nu, \alpha, \delta) + T_{UERS}(\nu)$$

Firxen et al. [arXiv:0901.0555]
Seiffert et al. [arXiv:0901.0559]

http://arcade.gsfc.nasa.gov

ARCADE 2 anomaly

PRL 107,271302 (2011), arxiv:1108.0569



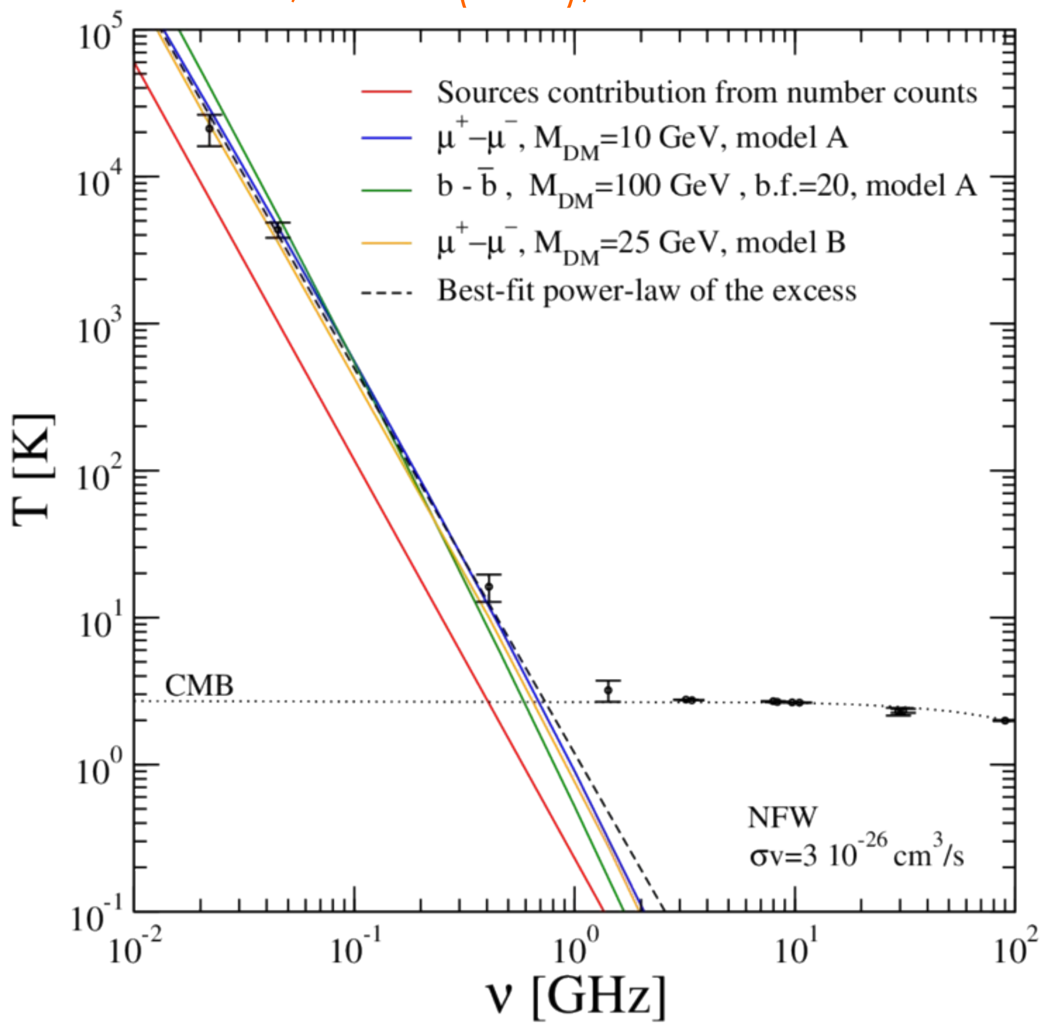
The source count is the key to understand the excess

The ARCADE excess needs of a extragalactic population of sources that dominates at low luminosity and have a steep radio spectrum

Could WIMPs do the job?

ARCADE 2 anomaly

PRL 107,271302 (2011), arxiv:1108.0569



DM can provide the missing signal

However, it is not unique

Alternative explanations

- Faint quasars
- Radio-quite AGNs
- Star forming galaxies
- Unresolved galactic sources(?)

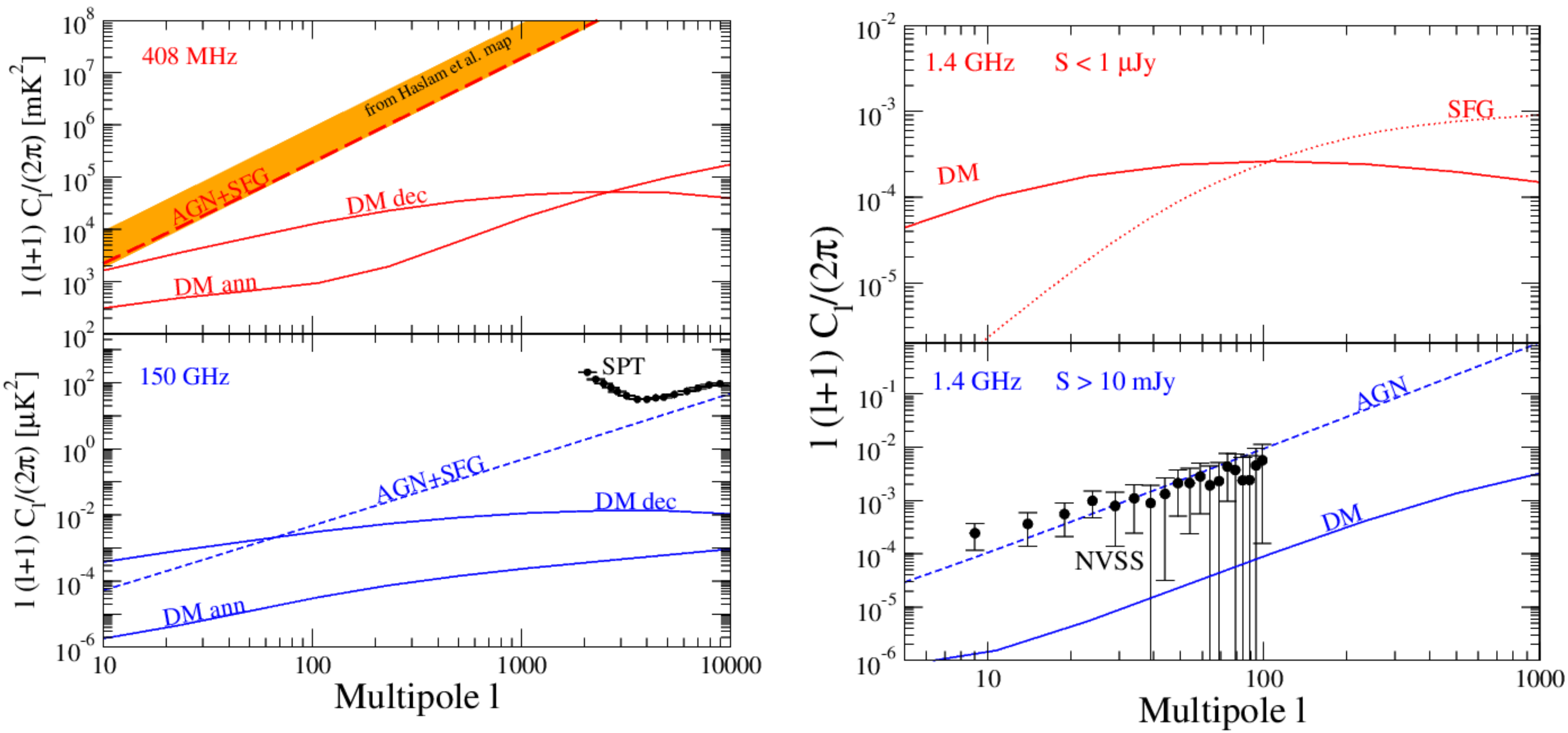
More details:

Gervasi et al. [arxiv:0803.4138]

Singal et al. [arxiv:0909.1997]

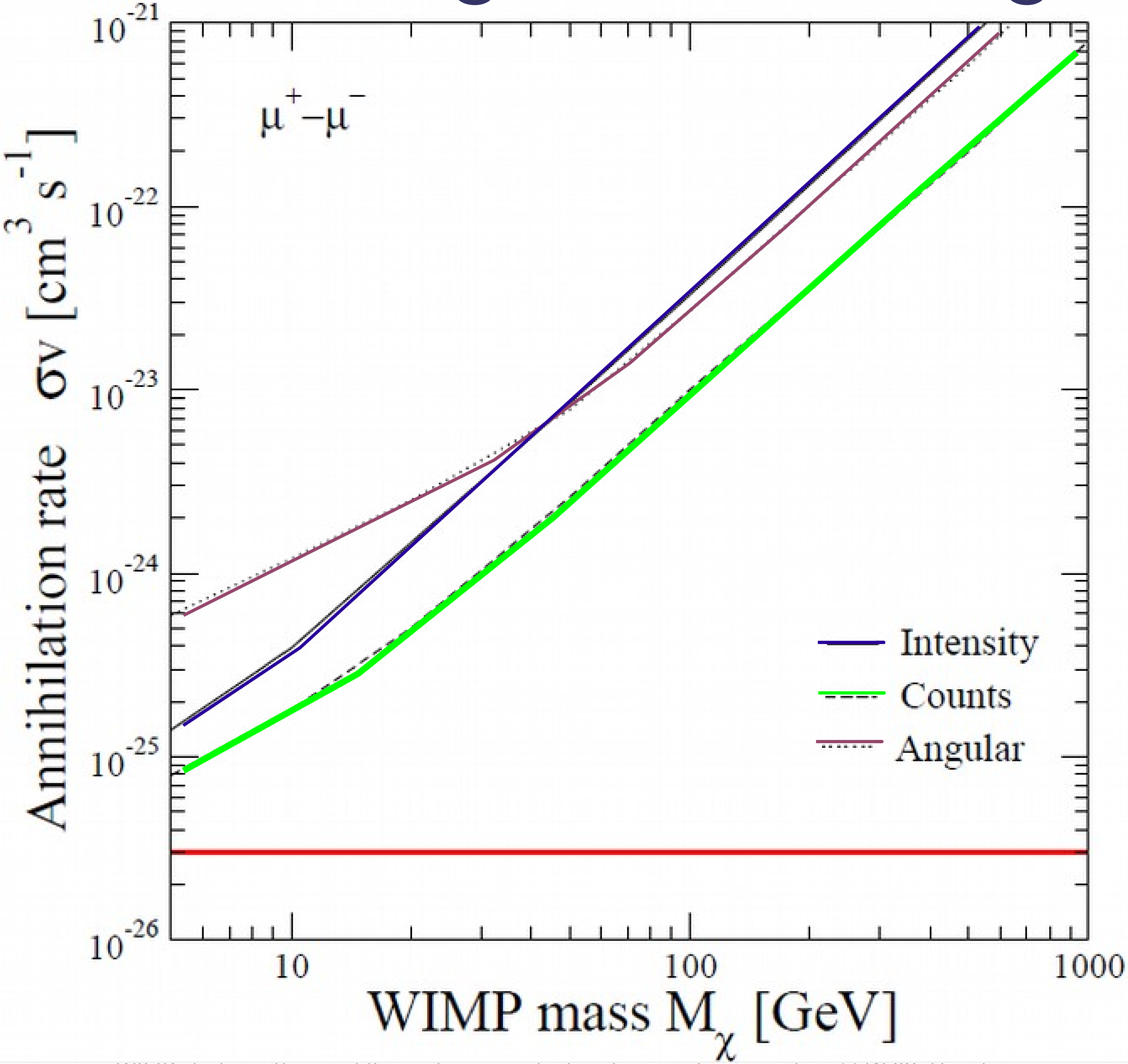
Beyond the extra-galactic background

[arxiv:1112.4517]



Power spectrum description of the extragalactic DM radio.
A full analysis and forecast are very challenging

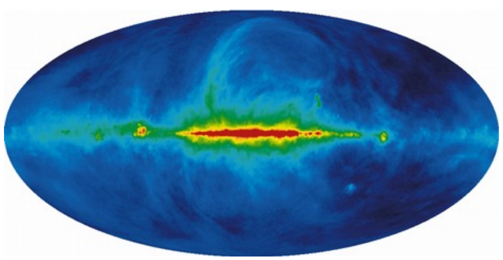
Beyond the extra-galactic background

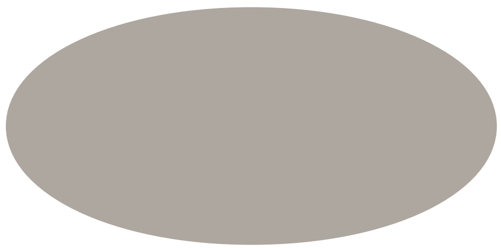


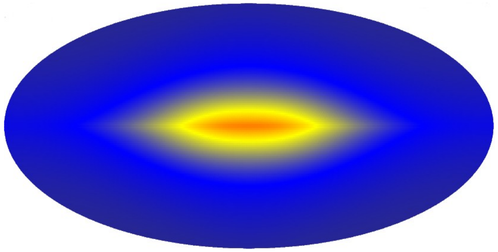
[arxiv:1112.4517]

The isotropic radio background revisited

[arxiv:1402.2218]



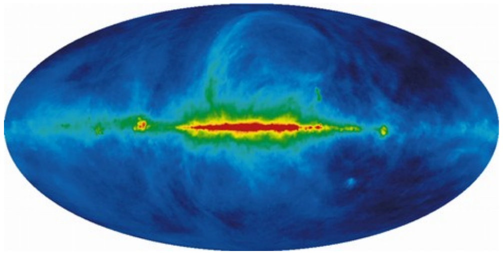


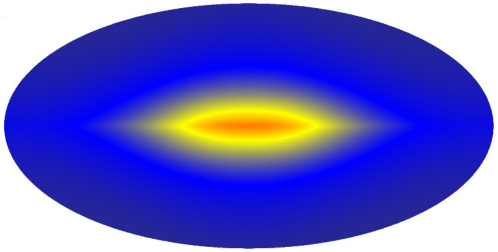


$$T(l,b) = T_E + T_S(l,b) + T_G(l,b)$$

The isotropic radio background revisited

[arxiv:1402.2218]

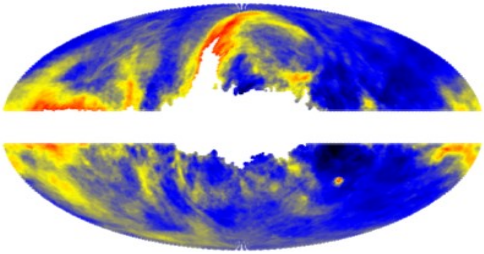




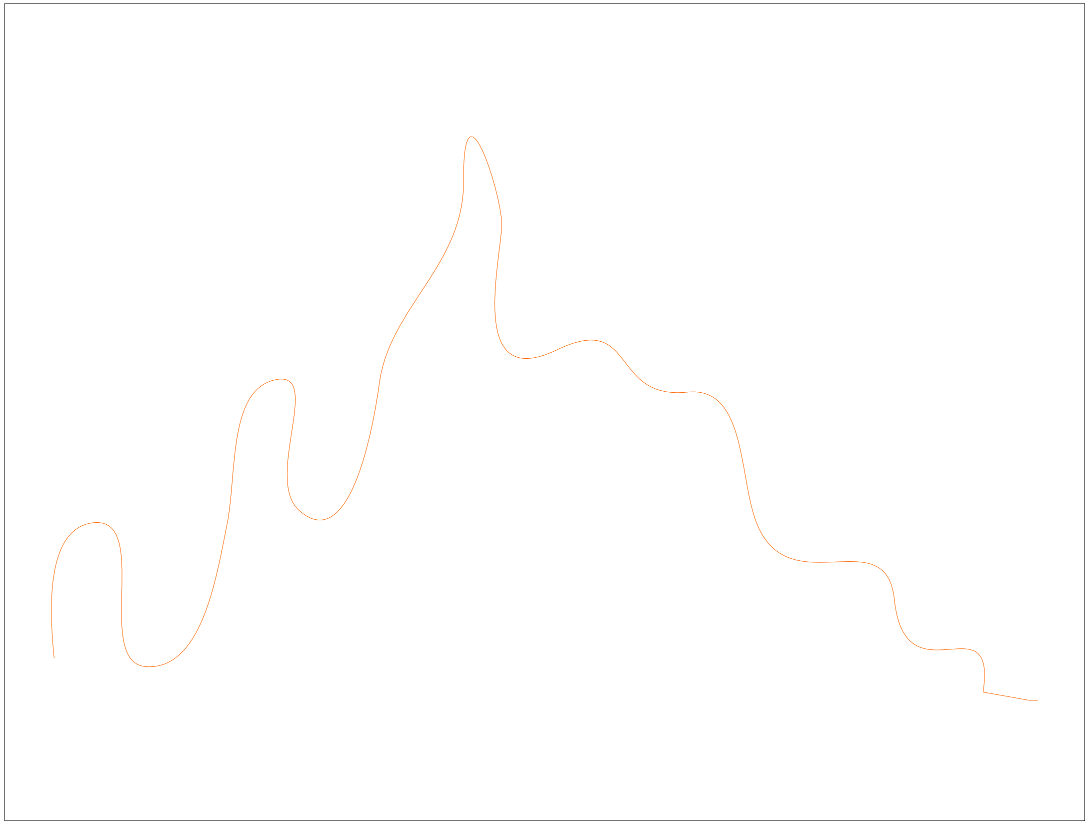
$$T_i^{\text{model}} = T_E + c_{\text{gal}} T_i^{\text{gal,synch}} + c_{\text{brem}} T_i^{\text{gal,brem}}$$

$$R_i = T_i^{\text{data}} - T_i^{\text{model}}$$

$$R_i > T_{R,i} + 5\sigma_i$$

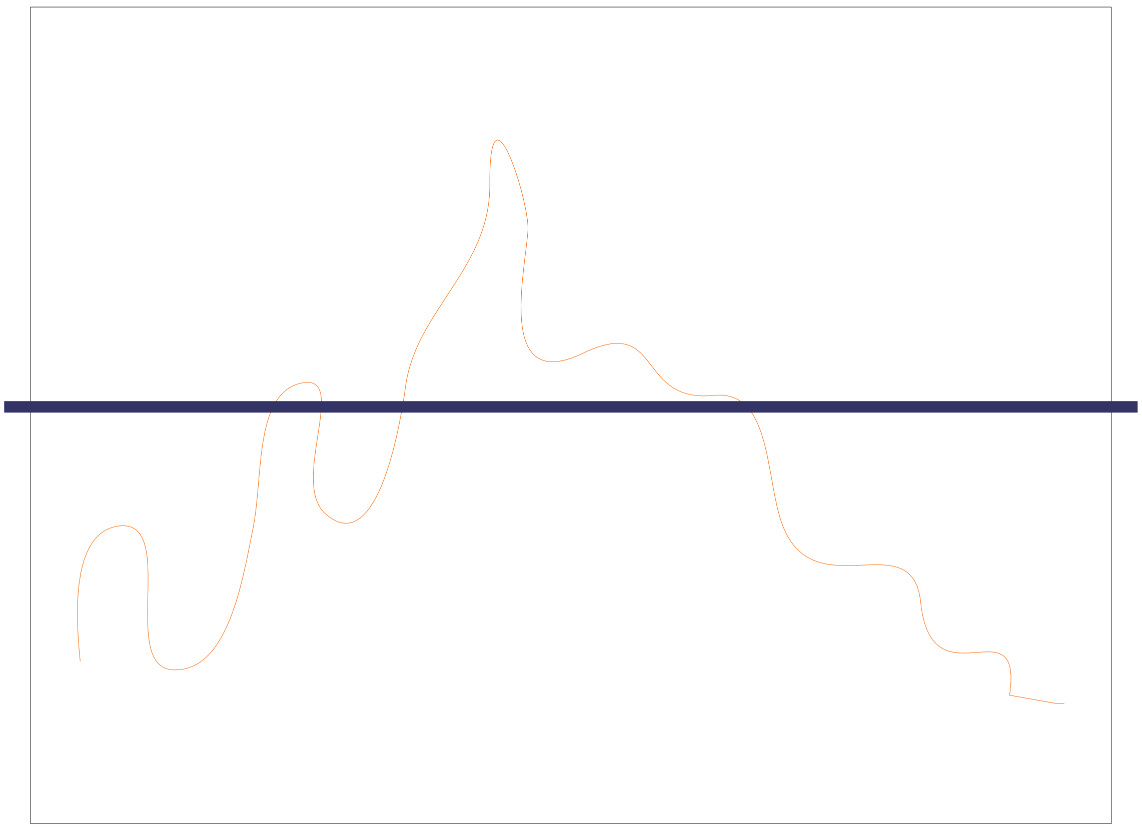


The method



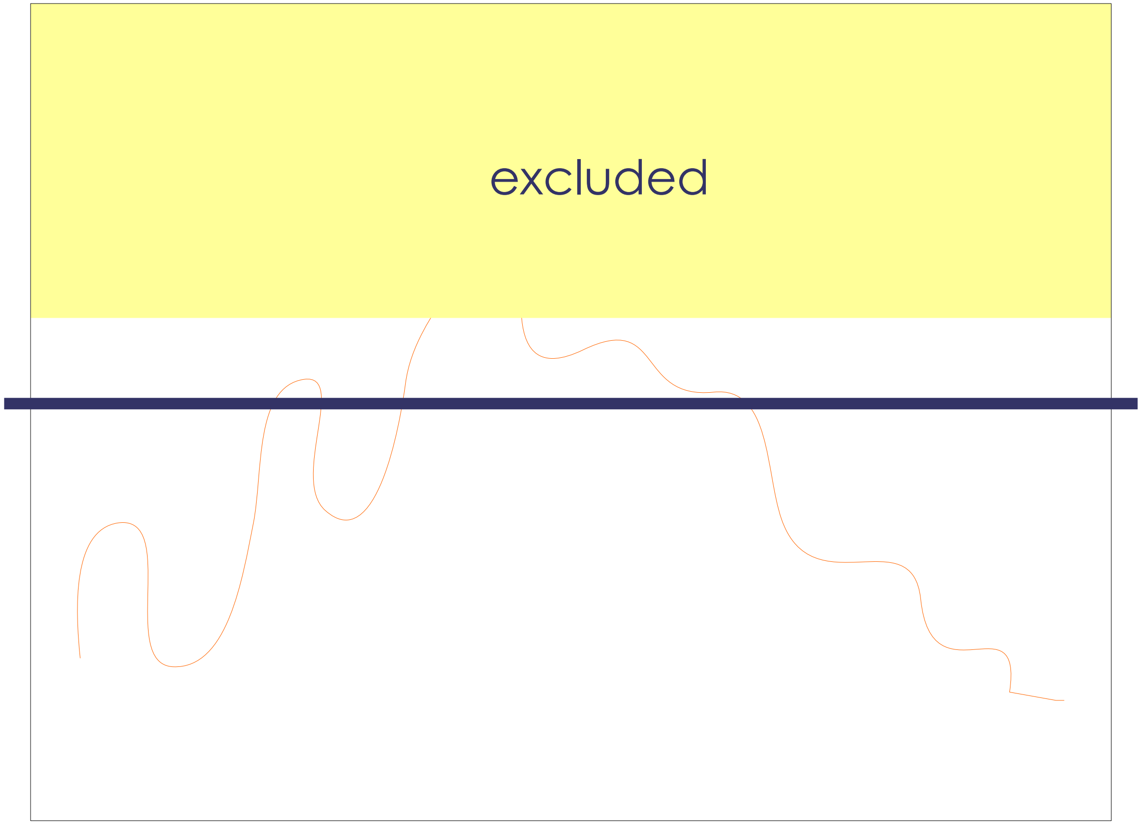
The data

The method

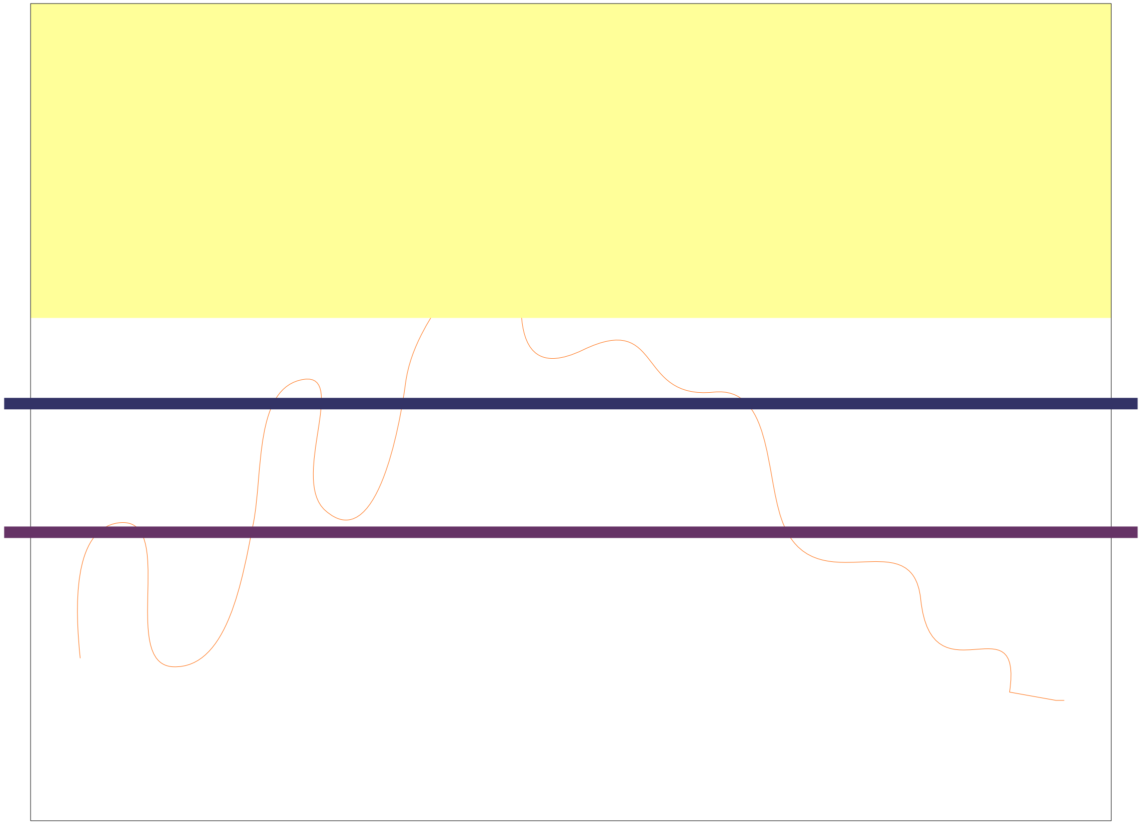


The mean

The method

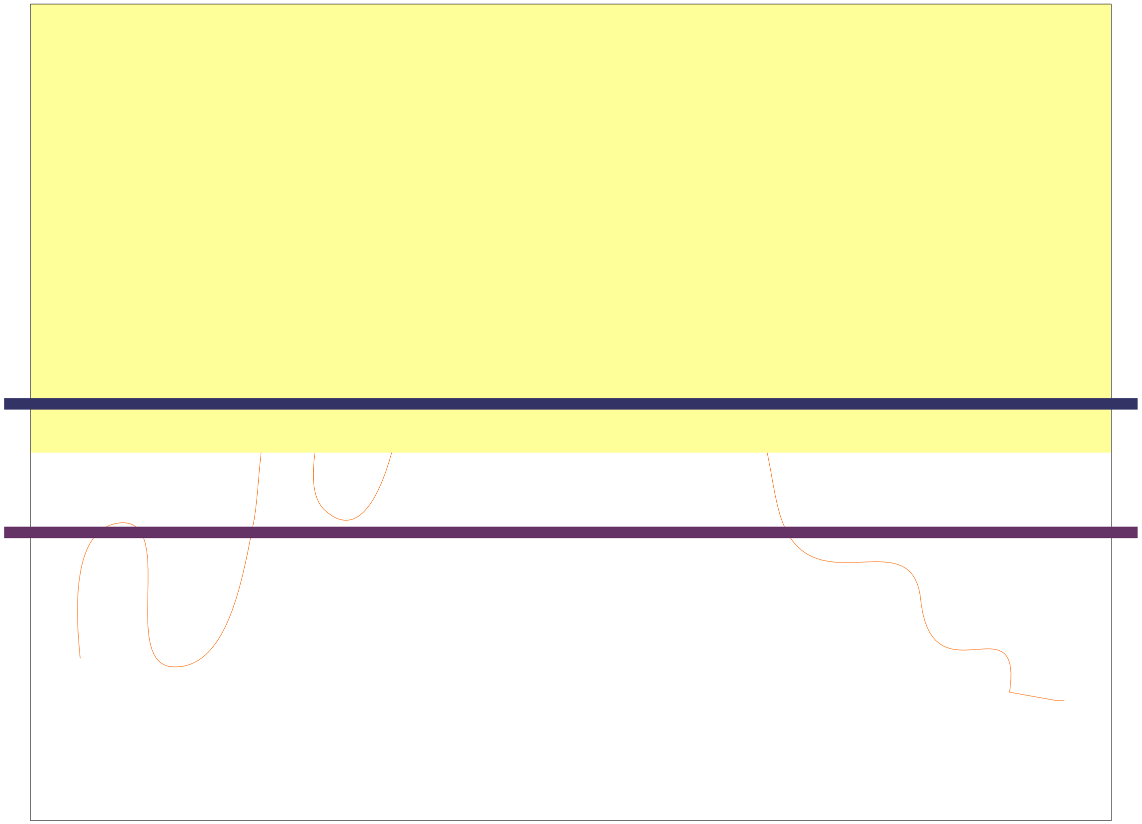


The method



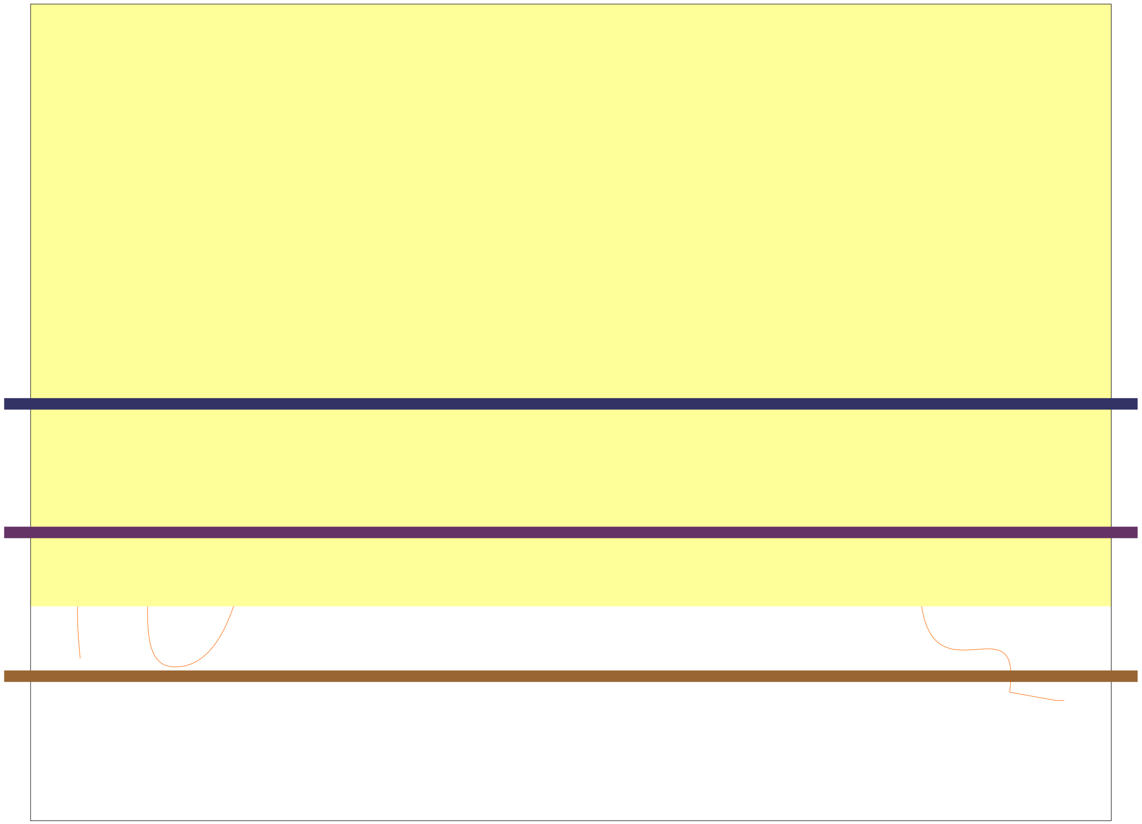
The new mean

The method



Many iterations

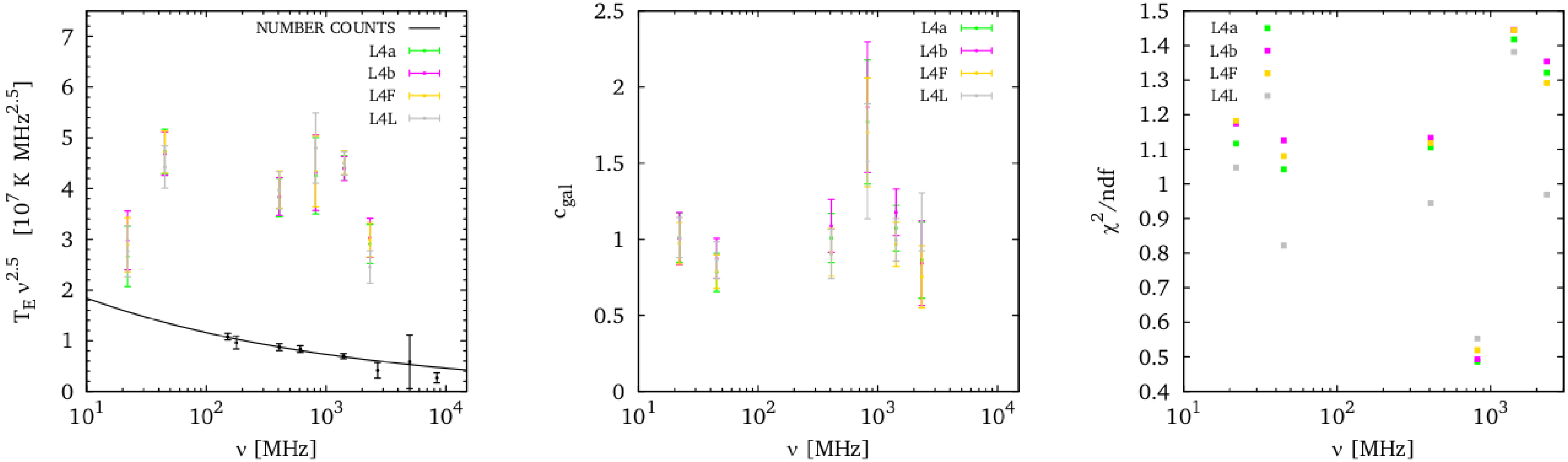
The method

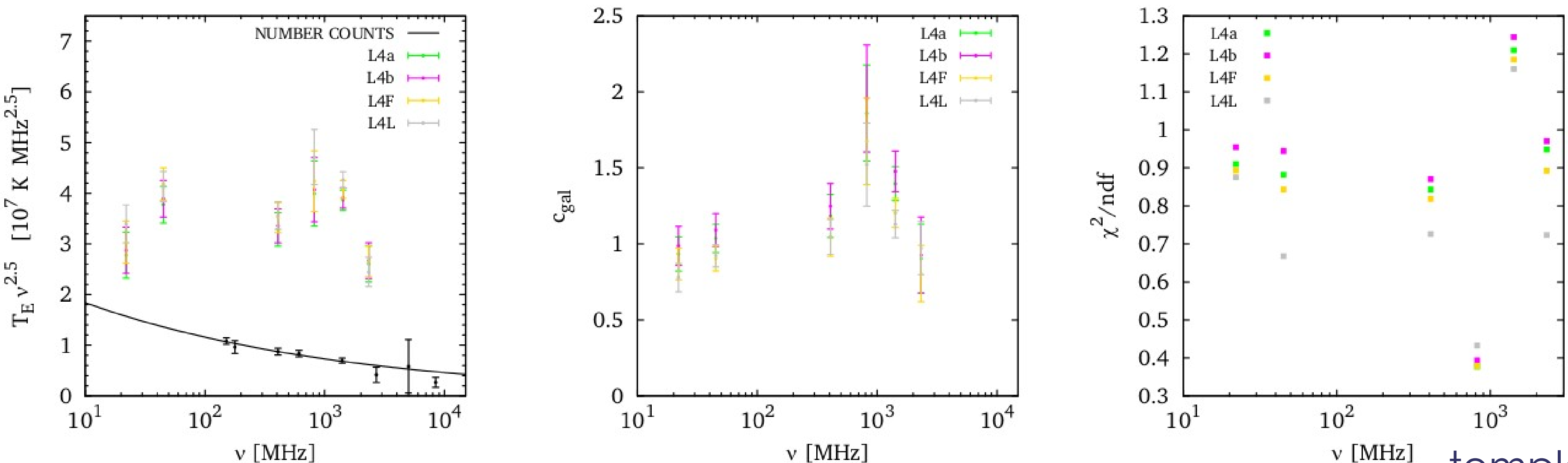


The final estimation
After convergence

Some results

mask

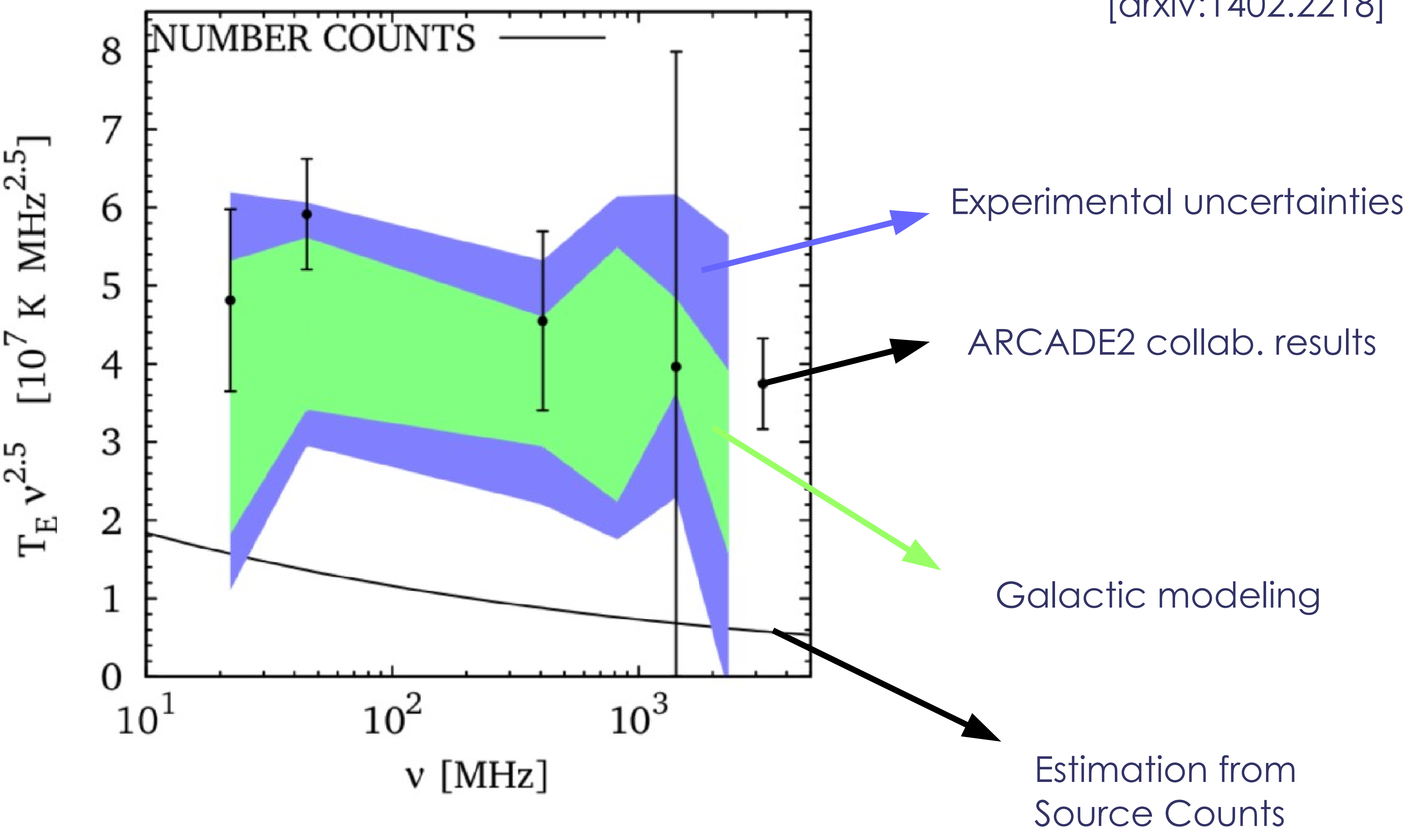




templates

The isotropic radio background revisited

[arxiv:1402.2218]



Conclusions

The (extra) galactic radio sky gives an alternative way to constrain WIMP dark matter

DM radio searches are able to explore regions with thermal cross section i.e. $\langle\sigma v\rangle = 3 \times 10^{-26}\ \mathrm{cm^3/s}$

Lower frequencies are more suitable to explore light DM candidates, however cross correlation with other observables are required (!)

The ARCADE 2 anomaly is still an unresolved issue

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